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STATISTICAL ANALYSIS OF THE PARAMETER TARGETING PRECISION FOR THE J-2 ROCKET ENGINE TEST PROGRAM

C. R. Tinsley

ARO, Inc.

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LARGE ROCKET FACILITY
ARNOLD ENGINEERING DEVELOPMENT CENTER
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NOTICES

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FOREWORD

The work reported herein was sponsored by the National Aeronautics and Space Administration (NASA), Marshall Space Flight Center (MSFC), under Program Element 921E, Project 9194.

The work presented herein was performed on test results obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), Arnold Air Force Station, Tennessee, under Contract F40600-69-C-0001. Program direction was provided by NASA/MSFC; engineering liaison was provided by North American Aviation, Inc., Rocketdyne Division, manufacturer of the J-2 rocket engine, and McDonnell Douglas Astronautics Company, manufacturer of the S-IVB stage. The test program was conducted from August 27, 1966, to October 8, 1968, under ARO project numbers KA1554, KA1801, and KA1901. The manuscript was submitted for publication on March 6, 1965.

This technical report has been reviewed and is approved.

Edgar D. Smith
Major, USAF
AF Representative, LRF
Directorate of Test

Roy R. Croy, Jr.
Colonel, USAF
Director of Test

ABSTRACT

Testing of the Rocketdyne J-2 engine using an S-IVB battleship stage was conducted at AEDC from July 1966 through October 1968 in Propulsion Engine Test Cell (J-4) of the Large Rocket Facility (LRF) in support of the J-2 application on the Saturn IB and Saturn V launch vehicles for the NASA Apollo program. Three engines were tested during the program for a total of 263 engine firings with eight additional nonfiring tests. Throughout this test program various temperature and pressure parameters were assigned target values at engine start for the purpose of assuring safe engine operation, for producing predicted flight conditions, or for duplicating actual flight conditions. The work reported herein is a basic statistical analysis performed on thirteen of these targeted parameters for the purpose of determining the precision with which the test facility met these engine start targets. The number of samples utilized in the analysis for each parameter range from 48 to 269, with only three parameters having a sample size of less than 187. With the exception of engine ambient altitude, calculations of arithmetic mean and standard deviation were performed, and the percent of targets met during the test program for each of the thirteen parameters was determined. A cumulative frequency diagram was constructed for engine ambient altitude. It was determined that throughout the test program the facility met 83.8 percent of all target requirements for the parameters under consideration.

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APPENDIXES

NOMENCLATURE

Engine Start	The time that the helium control and ignition phase solenoids are energized
n	Number of independent samples
s	Standard deviation estimated from a sample of the entire population $\left(\sqrt{\frac{(x - \bar{x})^2}{n - 1}}\right)$
x	The deviation between target center and the value actually attained
$\bar{x}$	The arithmetic mean, defined as the value from which the sum of the squares of the deviations from the central value is a minimum $\left(\frac{\Sigma x}{n}\right)$
σ	The standard deviation defined as the square root of the arithmetic mean of the squares of the deviations about the arithmetic mean $\left(\sqrt{\frac{(x-\bar{x})^2}{n}}\right)$

SECTION I
INTRODUCTION

Testing of the Rocketdyne J-2 engine using an S-IVB battleship stage (Fig. 1, Appendix I) was conducted at AEDC from July 1966 through October 1968 in Propulsion Engine Test Cell (J-4) (Figs. 2 and 3) of the Large Rocket Facility (LRF) in support of the J-2 application on the Saturn IB and Saturn V launch vehicles for the NASA Apollo program. Engines tested during this program were: (1) J-2052 (88 engine starts with 1402-sec total firing duration), (2) J-2047, (115 engine starts with 1483-sec total firing duration), and (3) J-2036-1 (60 engine starts with 829-sec total firing duration) (Ref. 1). A total of eight additional nonfiring tests was conducted during the test program. Except for isolated cases, all testing was accomplished at pressure altitudes of approximately 100,000 ft (geometric pressure altitude, Z, Ref. 2) at engine start.

The investigation reported herein consists of a basic statistical analysis of the results obtained from the prefire conditioning of eight engine components (nine temperature and three pressure parameters) and from the targeted engine ambient altitude at engine start. The analysis consists of the construction of a cumulative frequency diagram for engine ambient altitude and the calculation of arithmetic mean and standard deviation for the remaining twelve parameters. The percentage of targets met during the test program was also calculated for the parameters. The test data utilized in this investigation are presented in Table I (Appendix II) and were obtained from Refs. 3 through 32.

This analysis is concerned only with data from successful tests. Parameter conditioning is not considered for tests which were aborted. The results of this analysis do not reflect the best capability of the facility as far as meeting targeted parameter requirements is concerned. Throughout the entire J-2 engine test program, only five percent of the tests were aborted because of problems related to parameter conditioning. In general, the few tests which were aborted because of parameter conditioning were done so as a result of the value of the parameter being outside the safe start region of engine operation. In almost every instance, the value of the parameter being outside the start target bandwidth was not considered of great enough importance to warrant a firing abort. Had a higher number of tests been aborted in these cases, then this analysis would reflect more accurately the actual capability of the facility regarding parameter conditioning precision.

SECTION II
TEST ARTICLE

2.1 J-2 ROCKET ENGINE

The test article was a J-2 rocket engine (Fig. 4) designed and developed by Rocketdyne Division of North American Aviation, Inc. The engine uses liquid oxygen and liquid hydrogen as propellants and was operated over a thrust range from 180,000 to 250,000 lb_f at an oxidizer-to-fuel ratio from 4.3 to 5.5.

The J-2 rocket engine features the following major components:

1. Thrust Chamber - The tubular-walled, bell-shaped thrust chamber consists of an 18.6-in.-diam combustion chamber (8.0 in. long from the injector mounting to the throat inlet) with a characteristic length (L*) of 24.6 in., a throat area of 170.4 $in.^2$, and a divergent nozzle with an expansion ratio of 27.1. Thrust chamber length (from the injector flange to the nozzle exit) is 107 in. Cooling is accomplished by the circulation of engine fuel flow downward from the fuel manifold through 180 tubes and then upward through 360 tubes to the injector.

2. Thrust Chamber Injector - The injector is a concentric-orificed (concentric fuel orifices around the oxidizer post orifices), porous-faced injector. The porous material, forming the injector face, allows approximately 3.5 percent of total fuel flow to transpiration cool the face of the injector.

3. Augmented Spark Igniter - The augmented spark igniter unit is mounted on the thrust chamber injector and supplies the initial energy source to ignite propellants in the main combustion chamber. The augmented spark igniter chamber is an integral part of the thrust chamber injector. Fuel and oxidizer are ignited in the combustion area by two spark plugs.

4. Fuel Turbopump - The turbopump is composed of a two-stage turbine-stator assembly, an inductor, and a seven-stage axial-flow pump. The pump is self-lubricated and nominally produces, at rated conditions, a head rise of 35,517 ft (1225 psia) of liquid hydrogen at a flow rate of 8414 gpm for a rotor speed of 26,702 rpm.

5. Oxidizer Turbopump - The turbopump is composed of a two-stage turbine-stator assembly and a single-stage centrifugal

pump. The pump is self-lubricated and nominally produces, at rated conditions, a head rise of 2117 ft (1081 psia) of liquid oxygen at a flow rate of 2907 gpm for a rotor speed of 8572 rpm.

6. Gas Generator - The gas generator consists of a combustion chamber containing two spark plugs, a pneumatically operated control valve containing oxidizer and fuel poppets, and an injector assembly. The oxidizer and fuel poppets provide a fuel lead to the gas generator combustion chamber. The high energy gases produced by the gas generator are directed to the fuel turbine and then to the oxidizer turbine (through the turbine crossover duct), before being exhausted into the thrust chamber at an area ratio (A/A_t) of approximately 11.

7. Propellant Utilization Valve - The motor-driven propellant utilization valve is mounted on the oxidizer turbopump and bypasses liquid oxygen from the discharge to the inlet side of the pump to vary engine mixture ratio.

8. Propellant Bleed Valves - The pneumatically operated fuel and oxidizer bleed valves provide pressure relief for the boiloff of propellants trapped between the battleship stage prevalves and main propellant valves at engine shutdown.

9. Integral Hydrogen Start Tank and Helium Tank - The integral tanks consist of a 7258-in.^{3} sphere for hydrogen with a 1000-in.^{3} sphere for helium located within it. Pressurized gaseous hydrogen in the start tank provides the initial energy source for spinning the propellant turbopumps during engine start. The helium tank provides a helium pressure supply to the engine pneumatic control system.

10. Oxidizer Turbine Bypass Valve - The pneumatically actuated oxidizer turbine bypass valve provides control of the fuel turbine exhaust gases directed to the oxidizer turbine in order to control the oxidizer-to-fuel turbine spinup relationship. The fuel turbine exhaust gases which bypass the oxidizer turbine are discharged into the thrust chamber.

11. Main Oxidizer Valve - The main oxidizer valve is a pneumatically actuated, two-stage butterfly-type valve located in the oxidizer high pressure duct between the turbopump and the main injector. The first-stage actuator positions the main oxidizer valve at the 14-deg position to obtain initial thrust chamber ignition; the second-stage actuator ramps the main oxidizer valve full-open to accelerate the engine to mainstage operation.

12. Main Fuel Valve - The main fuel valve is a pneumatically actuated butterfly-type valve located in the fuel high pressure duct between the turbopump and the fuel manifold.

13. Pneumatic Control Package - The pneumatic control package controls all pneumatically operated engine valves and purges.

14. Electrical Control Assembly - The electrical control assembly provides the electrical logic required for proper sequencing of engine components during operation.

15. Primary and Auxiliary Flight Instrumentation Packages - The instrumentation packages contain sensors required to monitor critical engine parameters. The packages provide environmental control for the sensors.

2.2 S-IVB BATTLESHIP STAGE

The S-IVB battleship stage is approximately 22 ft in diameter and 49 ft in length and has a maximum propellant capacity of 46,000 lb of liquid hydrogen and 199,000 lb of liquid oxygen. The propellant tanks, fuel above oxidizer, are separated by a common bulkhead. Propellant prevalves, in the low pressure ducts (external to the tanks), interfacing the stage and the engine, retain propellant in the stage until being admitted into the engine to the main propellant valves and serve as emergency engine shutoff valves. Propellant recirculation pumps in both fuel and oxidizer tanks are utilized to circulate propellants through the low pressure ducts and turbopumps before engine start to stabilize hardware temperatures near normal operating levels and to prevent propellant temperature stratification. Vent and relief valve systems are provided for both propellant tanks.

Pressurization of the fuel and oxidizer tanks was accomplished by facility systems using hydrogen and helium, respectively, as the pressurizing gases. The engine-supplied gaseous hydrogen for fuel tank pressurization during S-IVB flight was routed to the facility venting system.

2.3 TEST CELL

Test Cell J-4, Fig. 3, is a vertically oriented test unit designed for static testing of liquid-propellant rocket engines and propulsion systems at pressure altitudes of 100,000 ft. The basic cell construction provides a 1.5-million-lb_f-thrust capacity. The cell consists of four major

components: (1) test capsule, 48 ft in diameter and 82 ft in height, situated at grade level and containing the test article; (2) spray chamber, 100 ft in diameter and 250 ft in depth, located directly beneath the test capsule to provide exhaust gas cooling and dehumidification; (3) coolant water, steam, nitrogen (gaseous and liquid), hydrogen (gaseous and liquid), and liquid-oxygen and gaseous-helium storage and delivery systems for operation of the cell and test article; and (4) control building, containing test article controls, test cell controls, and data acquisition equipment. Exhaust machinery is connected with the spray chamber and maintains a minimum test cell pressure before and after the engine firing and exhausts the products of combustion from the engine firing. Before a firing, the facility steam ejector, in series with the exhaust machinery, provides a pressure altitude of 100, 000 ft in the test capsule.

The battleship stage and the J-2 engine were oriented vertically downward on the centerline of the diffuser-steam ejector assembly. This assembly consisted of a diffuser duct (20 ft in diameter by 150 ft in length), a centerbody steam ejector within the diffuser duct, a diffuser insert (13.5 ft in diameter by 30 ft in length) at the inlet to the diffuser duct, and a gaseous-nitrogen annular ejector above the diffuser insert. The diffuser insert was provided for dynamic pressure recovery of the engine exhaust gases and to maintain engine ambient pressure altitude (attained by the steam ejector) during the engine firing. The annular ejector was provided to suppress steam recirculation into the test capsule during steam ejector shutdown. The test cell was also equipped with (1) a gaseous-nitrogen purge system for continuously inerting the normal air in-leakage of the cell, (2) a gaseous-nitrogen repressurization system for raising test cell pressure, after engine cutoff, to a level equal to spray chamber pressure and for rapid emergency inerting of the capsule, and (3) a spray chamber liquid-nitrogen supply and distribution manifold for initially inerting the spray chamber and exhaust ducting and for increasing the molecular weight of the hydrogen-rich exhaust products.

SECTION III
CONDITIONING PROCEDURE

Three methods were employed in the prefire conditioning of engine components. These methods involved (1) routing of conditioning gas internally through the components, (2) routing of conditioning gas externally over the components, and (3) routing of conditioning liquid internally through the components.

Conditioning of the thrust chamber, crossover duct, and hydrogen start tank was accomplished by the internal routing of gas from a liquid-hydrogen/gaseous-helium heat exchanger through these components. Gas temperature could be regulated from ambient to within about 80°F of liquid-hydrogen temperature. Figure 5 includes a schematic representation of the thrust chamber and crossover duct conditioning systems. For the cases of one- and two-orbit restarts, crossover duct temperature targets were met by allowing the duct to cool to the desired temperature from a previous engine firing. A liquid-hydrogen/gaseous-hydrogen heat exchanger was utilized for start tank conditioning. Chilled hydrogen gas at a temperature and pressure which would yield the desired target values at engine start was flowed through the start tank. During the final seconds of the countdown, this hydrogen gas was isolated in the start tank until the tank was depleted during the engine start cycle. Figure 6 presents a schematic representation of the start tank conditioning system.

Conditioning of the main oxidizer valve closing control line, main oxidizer valve second stage actuator, helium regulator, and start tank discharge valve was accomplished by the external routing of helium gas over these components at the temperature to meet the requirements at engine start. In some cases the main oxidizer valve second-stage actuator was conditioned by opening the prevalves and permitting oxidizer into the engine. In this case the actuator was cooled by conductive heat transfer to the desired target values. Figure 5 includes a schematic representation of the main oxidizer valve, the helium regulator, and the start tank discharge valve conditioning systems. Figure 7 shows the actual manifolds utilized in temperature conditioning the main oxidizer valve actuator and the start tank discharge valve. Both manifolds were fabricated from 1/4-in. stainless steel tubing. The chilled gas outlet holes were 1/16 in. in diameter and were spaced 3/4 in. apart. Manifolds for the main oxidizer valve closing control line and the helium regulator were fabricated in a similar manner. All of these manifolds were constructed such that the chilled helium gas was flowed directly over the component being chilled.

Conditioning of both the fuel pump inlet and the oxidizer pump inlet was accomplished by the internal routing of liquid through these components. In both cases the temperature requirements were met by: (1) conditioning the propellant tank bulk temperatures to the values required to achieve the pump inlet targets and (2) recirculating propellants from the tanks through the turbopump systems by use of recirculation pumps. Pressure requirements were met by pressurizing both tanks in the final seconds of the countdown in order to achieve the target values at the pump inlets.

The desired engine ambient altitude was obtained by utilizing the facility steam ejector in series with exhaust machinery.

SECTION IV
INSTRUMENTATION

Instrumentation systems were provided for measuring, monitoring, and recording the targeted temperature and pressure parameters. Table III-1 (Appendix III) contains a list of these parameters, and Fig. III-1 shows the locations of the sensing points.

Measurements of pump inlet pressures, engine ambient pressure, and start tank pressure were made using strain-gage-type pressure transducers. Measurements of thrust chamber throat temperature, start tank temperature, and pump inlet temperatures were made using platinum resistance temperature transducers. The main oxidizer valve closing control line, main oxidizer valve second-stage actuator, and start tank discharge valve body temperature measurements were made using copper-constantan thermocouples. Crossover duct and helium regulator temperature measurements were made using iron-constantan thermocouples.

The data acquisition systems were calibrated by precision electrical shunt resistance substitution for the pressure transducers and resistance temperature transducer units and by voltage substitution for the thermocouples.

The types of data acquisition and recording systems used during this test program pertinent to the conditioned components, were: (1) a multiple-input digital data acquisition system scanning each parameter at 40 samples per second and recording on magnetic tape and (2) direct-inking, null-balance potentiometer-type X-Y plotters and strip charts. Applicable systems were calibrated before each test (atmospheric and altitude calibrations).

All of the parameters considered in this analysis were monitored in the control room on either strip charts or X-Y plotters; however, the data utilized in this analysis were taken from the multiple-input digital data acquisition system. Electrical signals to both the digital system and the visual monitors originated from the same temperature or pressure sensing element for each parameter; therefore, any difference that existed between the digital and monitoring systems are reflected in the data.

SECTION V
RESULTS AND DISCUSSION

5.1 METHOD OF DATA PRESENTATION

The results obtained from the prefire conditioning of eight engine components (twelve temperature and pressure parameters) and from the targeted engine ambient altitude at engine start are investigated in this analysis. Table I presents a list of these test results showing target values and values actually attained at engine start.

One of the first assumptions made in this analysis concerns the choice, in some cases, of the start target center value. The start targets considered in this analysis were originally stated as test requirements with a specified bandwidth. For instance, typical engine start targets were of the form 30.0 ± 1.5 psia, -295.0 ± 0.4°F, or $1350 {}^{+30}_{-\ 0}$ psia. For the first two of these examples, the target center is well defined. For the third example, the target center is obtained as follows:

$$\text{Target Center} = \frac{(1350 + 30) - (1350 - 0)}{2} + 1350 = 1365 \text{ psia}$$

All data were normalized by taking the difference between the required target center and the value actually obtained at engine start.

With the exception of two conditioned parameters and the engine ambient altitude, the start targets for each individual parameter contain not only different target values of temperature or pressure, but also different target bandwidths. For example, target values for the thrust chamber throat temperature conditioning contain twenty different temperature values and six target bandwidths. Thrust chamber conditioning also contains cases in which one temperature value may have as many as four target bandwidths (for four separate firings). For example, different firings have had the following engine start targets:

-250 ± 50°F
-250 ± 25°F
-250 ± 15°F
-250 ± 10°F

Other examples such as this exist for a range of target temperatures from +50 to -275°F. Immediately, problems arise if one is interested in combining data with such a variety of target bandwidths and wide range of target temperatures.

After investigating the data, it was found that, in general, on a given component the precision of meeting either warm or cold target requirements was approximately the same. Therefore, the basic assumption was made in this analysis that, for any conditioned parameter, the precision and difficulty of hitting all targets was the same. This, then, allows only one investigation to be performed for each of the thirteen parameters. If the above assumption could not be made, then any type of basic statistical analysis would be difficult because of the large number of starting conditions which are present.

Three of the parameters (engine ambient altitude, fuel pump inlet temperature, and oxidizer pump inlet temperature) are slightly different from the others regarding target bandwidths. Engine ambient altitude had no target bandwidths, and the pump inlet temperatures had only one bandwidth throughout the test program.

The next step in the investigation was to construct histograms for all parameters except engine ambient altitude. These are shown in Fig. 8. In each histogram the abcissa shows the deviation (psi or °F) between the requested start target center and the value actually attained at engine start, and the ordinate shows the number of times any particular deviation between the target center and attained values occurred. It may be noted that, in order to better exhibit the normality of the data, an unbiased grouping of data was employed. For instance, from Fig. 8g, thrust chamber throat temperature deviations (between target center and the values actually attained at engine start) ranging from -2.0 through +2.0 were placed in one group. Likewise, deviations ranging from +3.0 through +7.0 were placed in one group. An unbiased grouping similar to this was employed for each of the thirteen parameters.

Group size was arbitrarily chosen. The attempt was made to construct the groups large enough to exhibit normality of the data and yet to keep the group sizes as small as possible. This was accomplished by insuring that each histogram contained at least ten groups with at least eight occurrences in the group containing the greatest number of occurrences.

The histograms showed that data for the parameters were normally distributed to a degree sufficient for the employment of standard statistical methods. Therefore, the arithmetic mean, $\bar{x}$, and the estimate of the standard deviation, s(x), given by the equation

$$s(x) = \sqrt{\frac{(x - \bar{x})^2}{n - 1}}$$

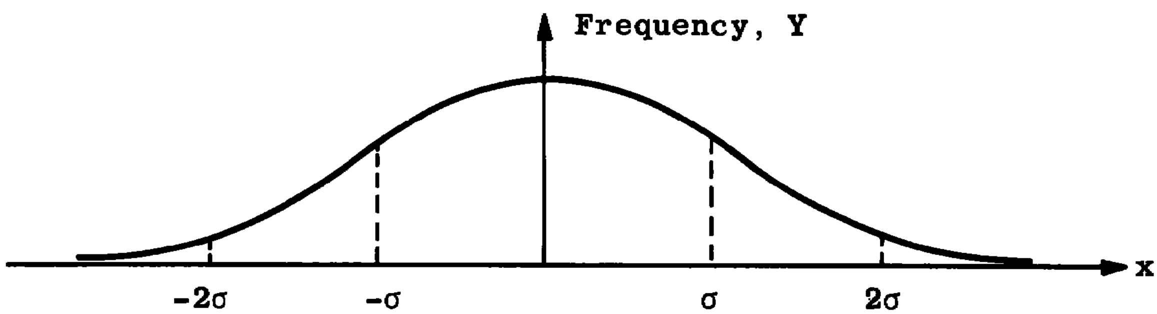
were calculated.

The standard deviation, σ, may be calculated utilizing the above equation by substituting n for n - 1. However, use of the standard deviation is valid only when n represents the total number of all possible observations (the entire population). Therefore, in practice an estimate of the standard deviation, s(x), is employed when the entire population is not known.

With a normally distributed variable, the standard deviation, σ, is a measure of the fraction of the distribution that is within a specified range of the mean. The equation of the normal distribution in terms of the relative frequency of occurrence as a function of the variable, x, the mean, $\bar{x}$, and the estimate of the standard deviation, s, is

$$Y = \frac{1}{s\sqrt{2\pi}} e^{-1/2\left(\frac{x - \bar{x}}{s}\right)^2}$$

The corresponding frequency distribution curve is of the form



The fraction of the total distribution that lies within the various ranges around the mean is shown in the following table:

Percent of Total Data	Error Magnitude, σ
50.00	$\bar{x} \pm 0.674$
68.26	$\bar{x} \pm 1.000$
90.00	$\bar{x} \pm 1.645$
95.00	$\bar{x} \pm 1.960$
95.45	$\bar{x} \pm 2.000$
99.73	$\bar{x} \pm 3.000$

Using the equations stated above, the arithmetic mean and the estimate of the standard deviation were calculated for each of the twelve parameters. These values were then utilized for each parameter to calculate their corresponding frequency distribution curves. Figure 8 shows these curves overlaid on their corresponding histograms.

Treatment of the engine ambient altitude differed somewhat from the other parameters. The target requirement for this parameter was that it be at or above 100, 000 ft at engine start. The data obtained for this parameter is somewhat skewed since the possibility existed for attaining altitudes as low as 60, 000 ft (40, 000 ft below target), whereas the possibility for attaining 140, 000 ft (40, 000 ft above target) did not exist. Therefore, a cumulative frequency diagram, Fig. 9, was constructed for this parameter rather than a histogram. On this diagram the ordinate at each point is the cumulative frequency or the number of members of the distribution that lie at or to the right of the value of the variable given on the X-axis.

The following sections deal individually with the parameters, providing specific assumptions utilized in the analyses and the results obtained. All data greater than 5 σ were omitted from this analysis; however, only four data points differed from the mean by this amount. Three of these data points resulted from the formation of ice on a filter in the oxidizer recirculation line causing oxidizer pump inlet pressure to deviate from the mean by amounts ranging from 6 to 10 σ. The fourth data point (6. 21 σ) was the result of an oxidizer pump inlet temperature target that was outside the capabilities of the conditioning system.

As previously mentioned, the distributions of all parameters, except engine ambient altitude, are assumed normal to a degree sufficient for the employment of standard statistical methods. However, it may be noted in the following analysis that practically all of the twelve parameters being considered (with regard to normality) are comprised of populations containing a greater number of members with deviations greater than 3 σ than are encountered in the classical normal population. An investigation of these data points which are greater than 3 σ revealed that in practically every case they were discovered to be abnormal at a time in the prefire countdown during which the test could have been aborted but was not considered of great enough importance to warrant an abort. Including these data points in the calculations of σ results in values of standard deviations which are somewhat conservative regarding the normal conditioning precision of the facility. This is because including these large-deviation data points causes the distributions to deviate from the normal distribution and to yield larger values for σ than would be obtained had the data been perfectly normal.

5.2 FUEL PUMP INLET PRESSURE

Fuel pump inlet pressure was targeted at engine start for a total of 269 times. Inlet pressure targets ranged from 21.5 to 46.0 psia.

Sixty-one percent of these targets contained ±0.5-psi bandwidths. thirty-one percent contained ±1.0-psi bandwidths, and eight percent contained ±1.5-psi bandwidths. The facility successfuly met 82.9 percent of these target requirements. Figure 8a shows the precision with which fuel pump inlet pressure requirements were met. Data from one of the firings (-4.8-σ deviation from the mean) is included in this analysis but is not represented on the histogram because of scaling difficulties. Figure 8a reveals that the arithmetic mean of the data is 0.058 psi greater than target center with a standard deviation of 0.613 psi.

5.3 FUEL PUMP INLET TEMPERATURE

Fuel pump inlet temperature was targeted at engine start for a total of 269 times. Inlet temperature targets ranged from -419.6 to -423.0°F. All targets contained bandwidths of ±0.4°F. The facility successfully met 83.6 percent of these target requirements. Figure 8b shows the precision with which fuel pump inlet temperature requirements were met. The figure reveals that the arithmetic mean of the data is 0.093°F warmer than target center with a standard deviation of 0.341°F.

5.4 OXIDIZER PUMP INLET PRESSURE

Oxidizer pump inlet pressure was targeted at engine start for a total of 266 times. Inlet pressure targets ranged from 28 to 48 psia. Seventy-five percent of these targets contained ±0.5-psi bandwidths, seventeen percent contained ±1.0-psi bandwidths, and eight percent contained ±1.5-psi bandwidths. The facility successfully met 91.7 percent of these target requirements. Figure 8c shows the precision with which oxidizer pump inlet pressure requirements were met. One of the firings (4.02-σ deviation from the mean) is included in this analysis but is not represented on the histogram because of scaling difficulties. Figure 8c reveals that the arithmetic mean of the data is 0.155 psi greater than target center with a standard deviation of 0.625 psi.

5.5 OXIDIZER PUMP INLET TEMPERATURE

Oxidizer pump inlet temperature was targeted at engine start for a total of 262 times. Inlet temperature targets ranged from -289.2 to -297.4°F. All targets contained bandwidths of ±0.4°F. The facility successfully met 80.5 percent of these target requirements. Figure 8d shows the precision with which oxidizer pump inlet temperature requirements were met. The figure reveals that the arithmetic mean of the

data is 0.002°F colder than target center with a standard deviation of 0.430°F.

5.6 START TANK PRESSURE

Start tank pressure was targeted at engine start for a total of 268 times. The pressure targets ranged from 600 to 1410 psia. Ninety-two percent of these targets contained ±10-psi bandwidths, and the remaining eight percent contained bandwidths ranging from ±12.5 to ±25 psi. The facility successfully met 86.2 percent of these target requirements. Figure 8c shows the precision with which start tank pressure requirements were met. The figure reveals that the arithmetic mean of the data is 0.80 psi below target center with a standard deviation of 8.83 psi.

5.7 START TANK TEMPERATURE

Start tank temperature was targeted at engine start for a total of 268 times. The temperature targets ranged from +50 to -300°F. Ninety-two percent of these targets contained ±10°F bandwidths, and the remaining eight percent contained bandwidths ranging from ±12.5 to ±30°F. The facility successfully met 97.0 percent of these target requirements. Figure 8f shows the precision with which requirements were met. The figure reveals that the arithmetic mean of the data is 1.65°F colder than target center with a standard deviation of 4.49°F.

5.8 THRUST CHAMBER THROAT TEMPERATURE

Thrust chamber throat temperature was targeted at engine start for a total of 187 times. The temperature targets ranged from +50 to -275°F. Forty-six percent of these targets contained ±25°F bandwidths, forty percent contained ±15°F bandwidths, ten percent contained ±10°F bandwidths, and the remaining four percent contained bandwidths ranging from ±7.5 to ±50°F. The facility successfully met 89.4 percent of these target requirements. Figure 8g shows the precision with which thrust chamber throat temperature requirements were met. The figure reveals that the arithmetic mean of the data is 3.1°F colder than target center with a standard deviation of 11.0°F.

Thirty-eight additional tests had an ambient temperature (50°F) start target; however, the precision with which these targets were met was not controlled. Therefore, these tests are not considered in this analysis.

5.9 CROSSOVER DUCT TEMPERATURE

Crossover duct temperature was targeted at engine start for a total of 230 times. The temperature targets ranged from 170 to -100°F. Twenty-nine percent of these targets contained ±25°F bandwidths, twenty percent contained ±7.5°F bandwidths, seventeen contained ±15°F bandwidths, eleven percent contained ±50°F bandwidths, ten percent contained ±20°F bandwidths, and the remaining thirteen percent contained bandwidths ranging from ±2.5 to ±17.5°F. The facility successfully met 78.7 percent of these target requirements. Figure 8h shows the precision with which crossover duct temperature requirements were met. The figure reveals that the arithmetic mean of the data is 0.8°F warmer than target center with a standard deviation of 18.3°F.

During different phases of J-2 engine testing, a varying number of temperature probes were attached to the crossover duct. To be consistent, this analysis is composed of data taken from one thermocouple only (TFTD-3) which was utilized throughout the test program.

5.10 MAIN OXIDIZER VALVE CLOSING CONTROL LINE TEMPERATURE

Main oxidizer valve closing control line temperature was targeted at engine start for a total of 60 times. The temperature targets ranged from 50 to -150°F. Sixty-four percent of these targets contained ±10°F bandwidths, eighteen percent contained ±12.5°F bandwidths, and the remaining eighteen percent contained bandwidths ranging from ±15 to ±25°F. The facility successfully met 48.3 percent of these target requirements. Figure 8i shows the precision with which main oxidizer valve closing control line temperature requirements were met. One of the firings (4.58-σ deviation from the mean) is included in this analysis but is not represented on the histogram because of scaling difficulties. Figure 8i reveals that the arithmetic mean of the data is 8.5°F colder than target center with a standard deviation of 21.3°F.

5.11 MAIN OXIDIZER VALVE ACTUATOR TEMPERATURE

Main oxidizer valve actuator temperature was targeted at engine start for a total of 201 times. Temperature targets ranged from -40 to -250°F. Sixty-seven percent of these targets contained ±50°F bandwidths, twenty-four percent contained ±10°F bandwidths, and the remaining nine percent contained bandwidths ranging from ±5 to ±30°F. The facility successfully met 88.1 percent of these target requirements. Figure 8j shows the precision with which main oxidizer valve actuator tem-

perature requirements were met. The figure reveals that the arithmetic mean of the data is 0.2°F warmer than target center with a standard deviation of 22.5°F.

5.12 HELIUM REGULATOR TEMPERATURE

Helium regulator temperature was targeted at engine start for a total of 48 times. Temperature targets ranged from 50 to -150°F. Forty-five percent of these targets contained ±10°F bandwidths, twenty-seven percent contained ±12.5°F bandwidths, ten percent contained ±20°F bandwidths, and the remaining eighteen percent contained bandwidths ranging from ±5 to ±25°F. The facility successfully met 52.1 percent of these target requirements. Figure 8k shows the precision with which helium regulator temperature requirements were met. The figure reveals that the arithmetic mean of the data is 10.9°F colder than target center with a standard deviation of 14.4°F.

5.13 START TANK DISCHARGE VALVE BODY TEMPERATURE

Start tank discharge valve body temperature was targeted at engine start for a total of 83 times. All were targeted at 50°F. Ninety-three percent of these targets contained ±25°F bandwidths, and seven percent contained ±50°F bandwidths. The facility successfully met 85.5 percent of these target requirements. Figure 8l shows the precision with which start tank discharge valve body temperature requirements were met. Two of the firings (4.48- and 4.75-σ deviations from the mean) are included in the analysis but are not represented on the histogram because of scaling difficulties. Figure 8l reveals that the arithmetic mean of the data is 15.5°F colder than target center with one standard deviation of 22.0°F.

5.14 ENGINE AMBIENT ALTITUDE

Engine ambient altitude was targeted at engine start for a total of 260 times. This includes all tests with the exception of eleven which were conducted at approximately 50,000 ft without utilizing the steam ejector. These eleven tests are not considered in this analysis. Engine ambient altitude differed from the twelve conditioned parameters in that no actual target bandwidths were placed on this parameter. However, there was the requirement that this parameter be at or above 100,000 ft at engine start. Figure 9 is the cumulative frequency diagram constructed for engine ambient altitude and reflects the precision with

which the altitude requirements were met. The figure reveals that the engine ambient altitude was above 104, 000 ft for one-half of the tests. The facility successfully met 74. 5 percent of the target requirements.

Table II is composed of a list, for the targeted parameters, of arithmetic mean location, standard deviation, and percent of targets met by the facility. The positive sign indicates either a pressure higher than target center or a temperature warmer than target center. The negative sign indicates either a pressure lower than target center or a temperature colder than target center.

As a result of the long duration of the J-2 engine test program and the large number of targeted parameters throughout the program, the facility has gained considerable knowledge with regard to its precision and capability of meeting targeted parameter requirements. The combination of this facility experience and the mathematical results presented herein should be of value in setting bandwidths for future targeted parameters.

SECTION VI
SUMMARY OF RESULTS

The results of the investigation performed on thirteen targeted parameters at engine start for the J-2 engine test program at AEDC are summarized as follows:

1. The investigation revealed that, in general, targeting precision was not influenced by either target values or bandwidths.
2. Throughout the J-2 engine test program, the facility met 83. 8 percent of all target requirements for those parameters under consideration.
3. The highest percentage of targets was met for the start tank temperature (97. 0 percent with 268 data points), and the lowest percentage was for the main oxidizer valve closing control line temperature (48. 3 percent with 60 data points).
4. Engine ambient altitude was above 104, 000 ft one-half of the time that it was a targeted parameter and was above 100, 000 ft 74. 5 percent of the time.
5. The data presented do not represent the best targeting capability of the facility, since some tests could have been aborted for failure to meet certain targets, but were not because these

parameters were not considered sufficiently important for the test objectives of the particular test involved.

6. Although twelve of the thirteen parameters included in this survey were treated as normally distributed, a higher frequency of data occurred in the 3- to 5-σ range, for some parameters, than is consistent with the theoretical normal distribution.

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APPENDIXES

I. ILLUSTRATIONS
II. TABLES
III. INSTRUMENTATION

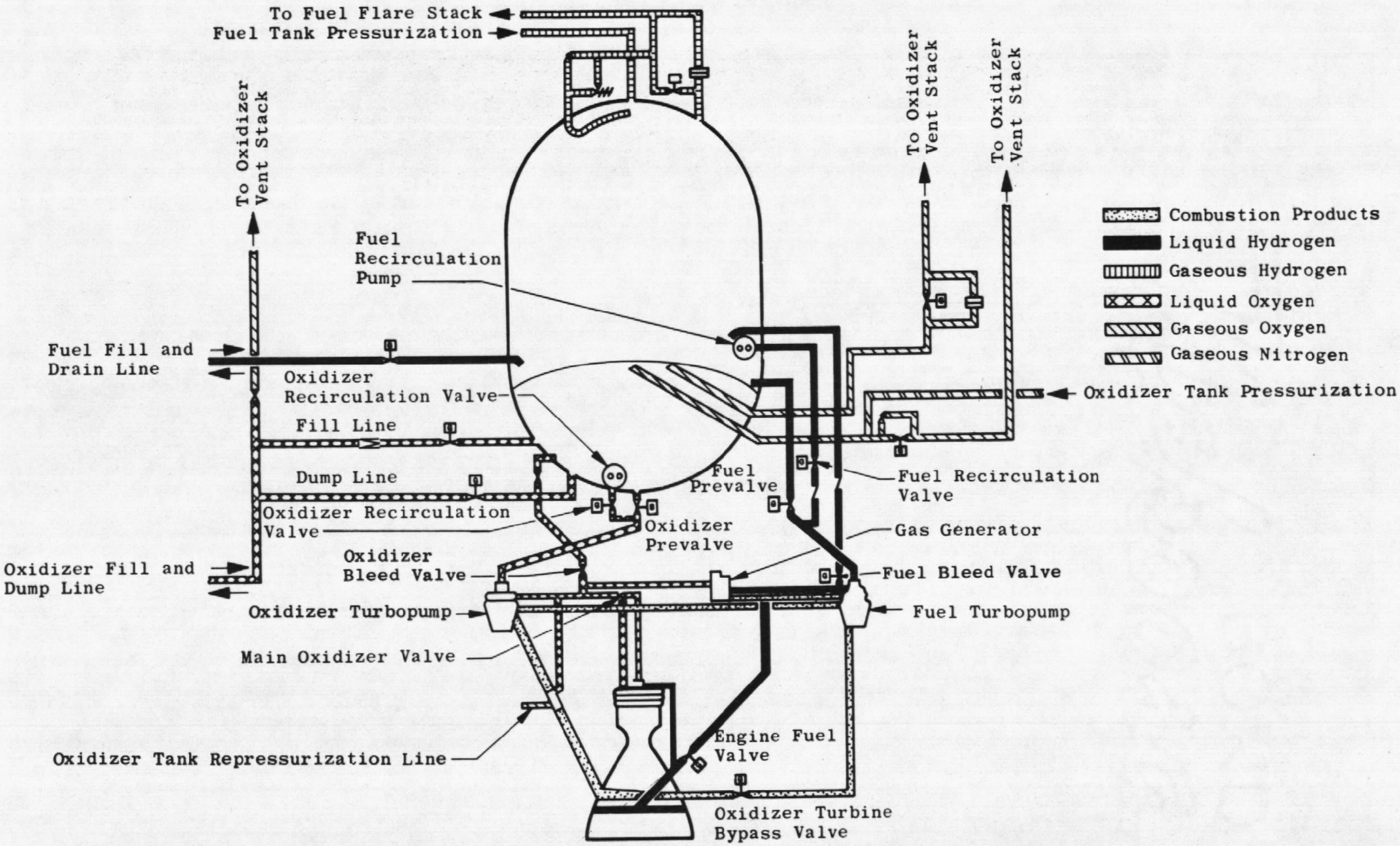


Fig. 1 S-IVB Battleship Stage/J-2 Rocket Engine Schematic

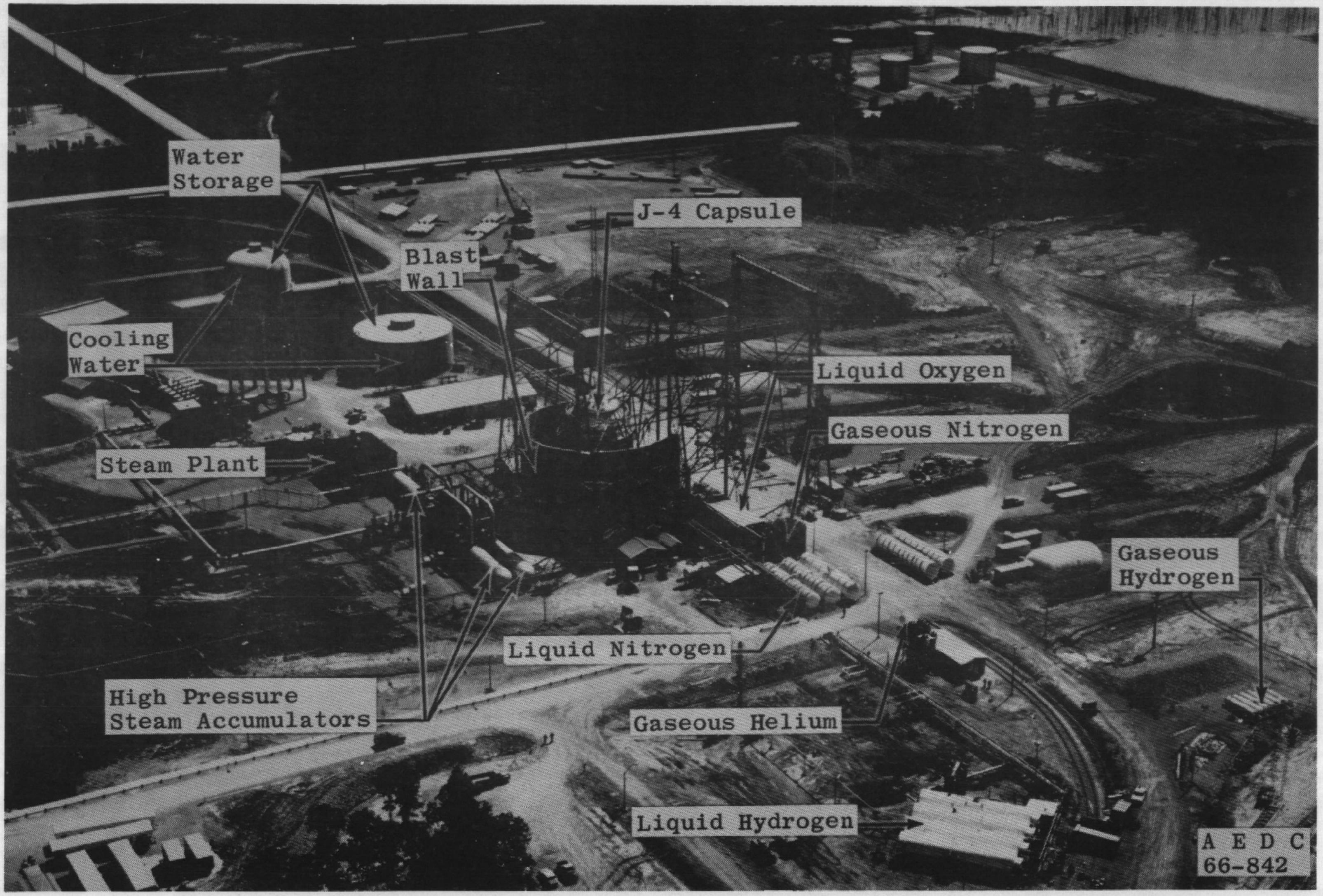


Fig. 2 Test Cell J-4 Complex

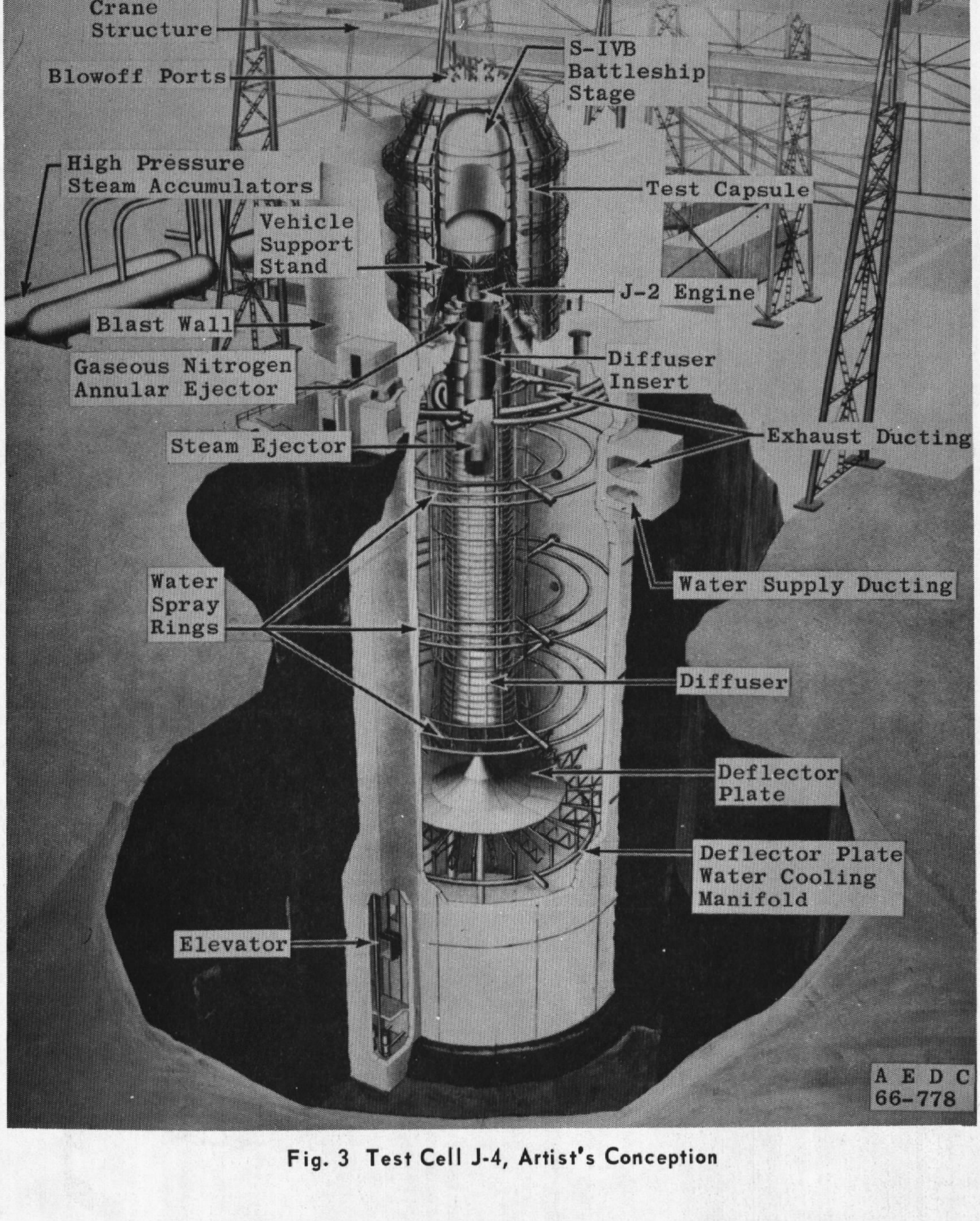


Fig. 3 Test Cell J-4, Artist's Conception

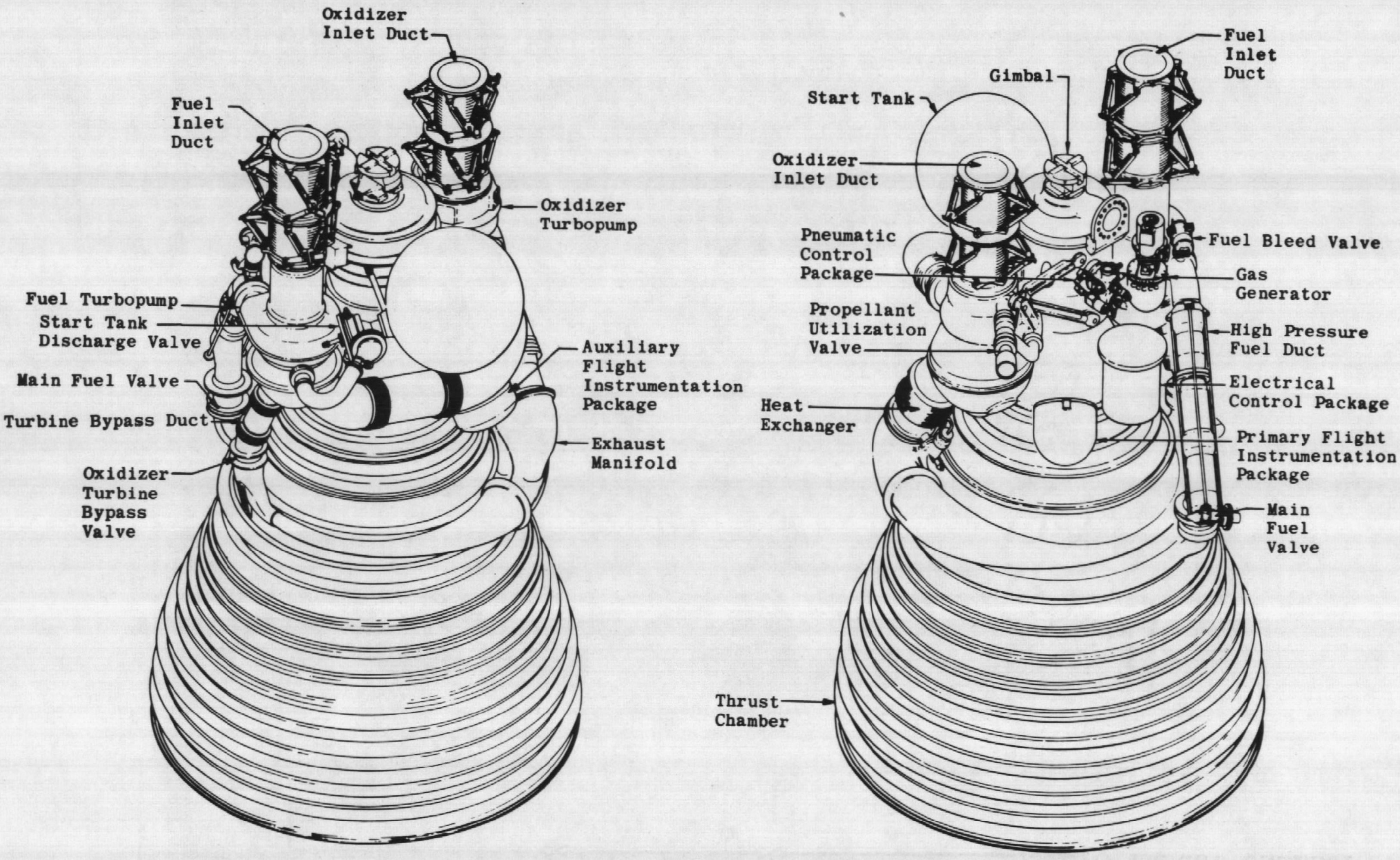


Fig. 4 Engine Details

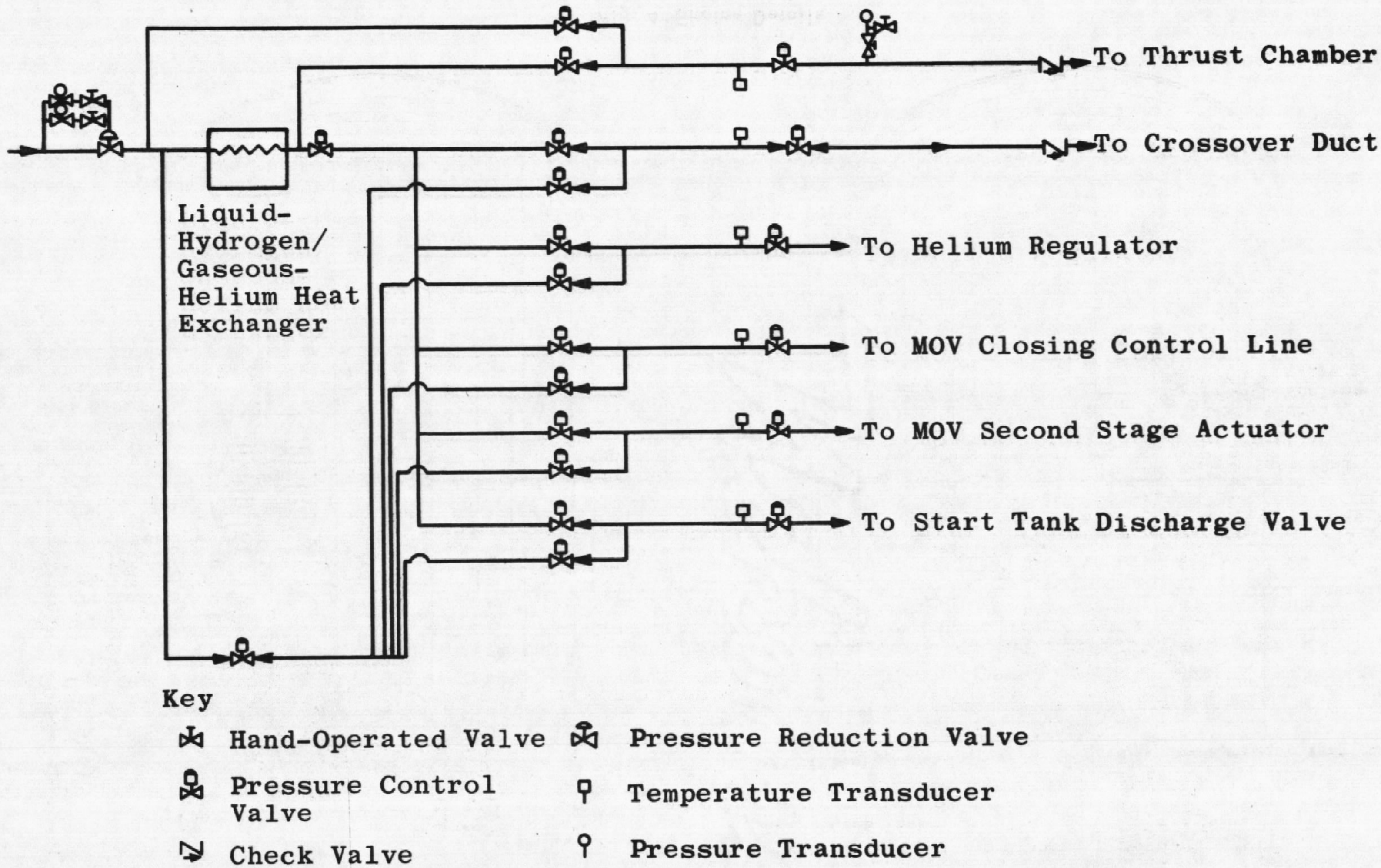


Fig. 5 Liquid-Hydrogen/Gaseous-Helium Heat Exchanger Conditioning System

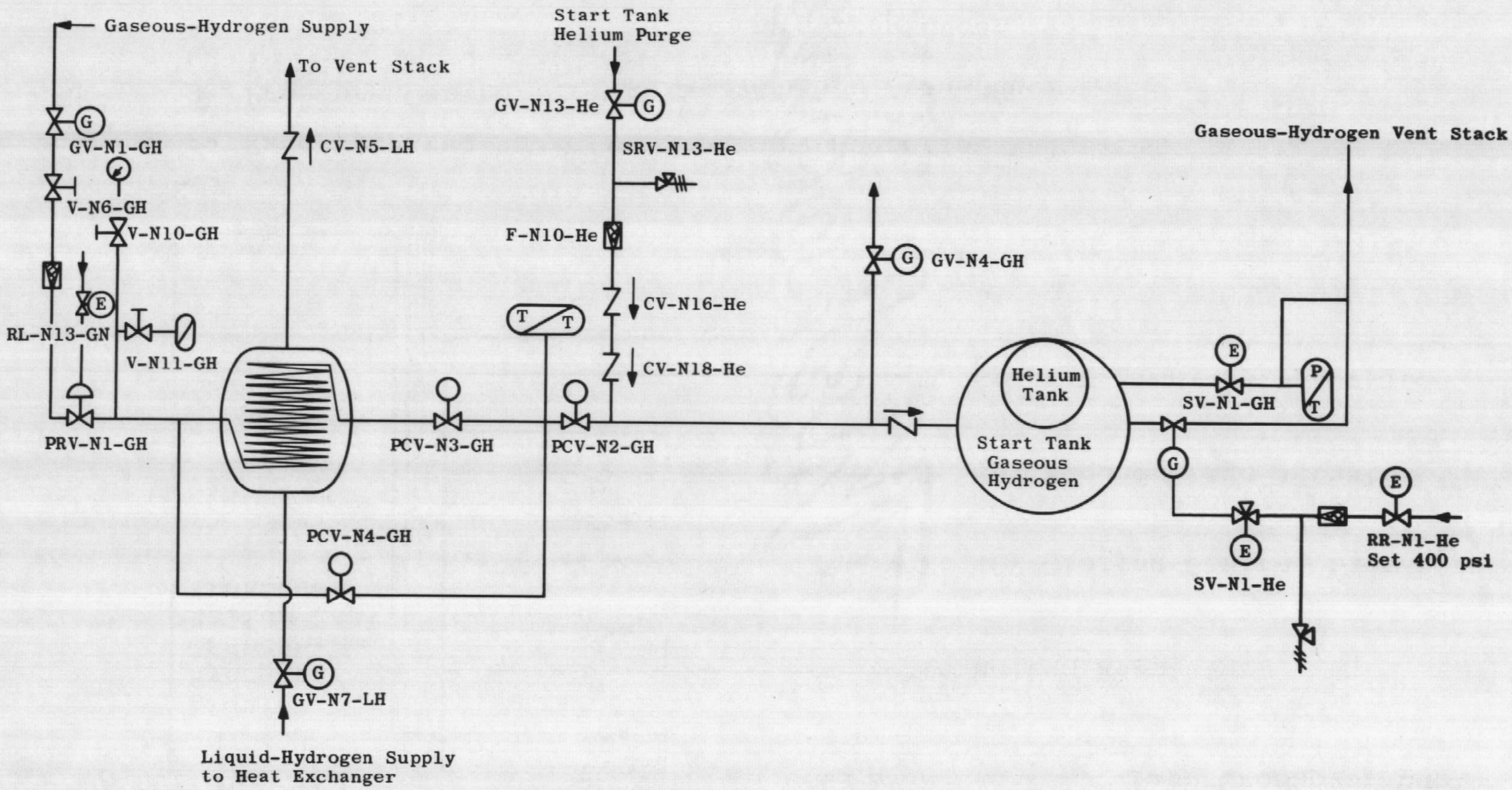


Fig. 6 Liquid-Hydrogen/Gaseous-Hydrogen Heat Exchanger Conditioning System

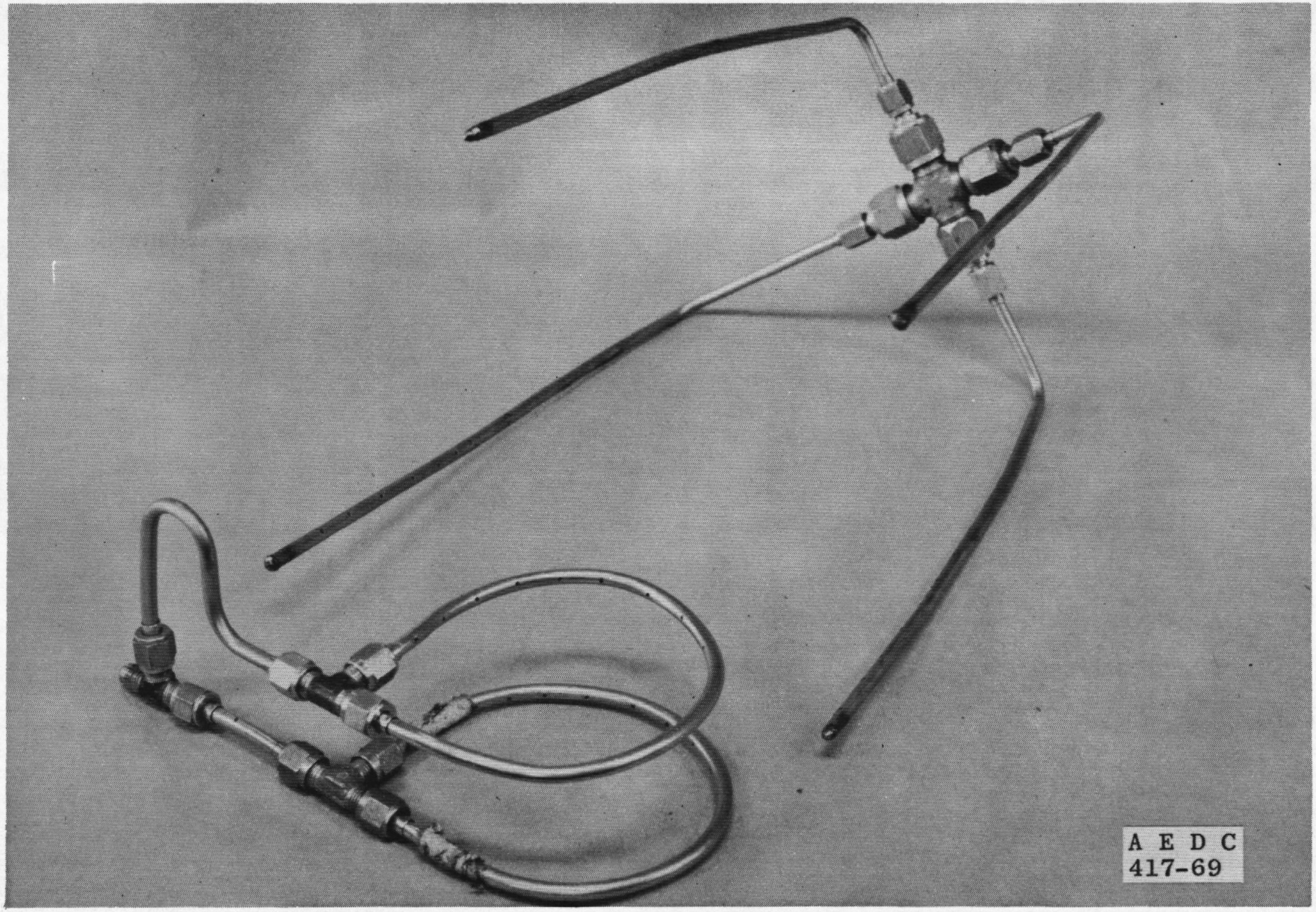
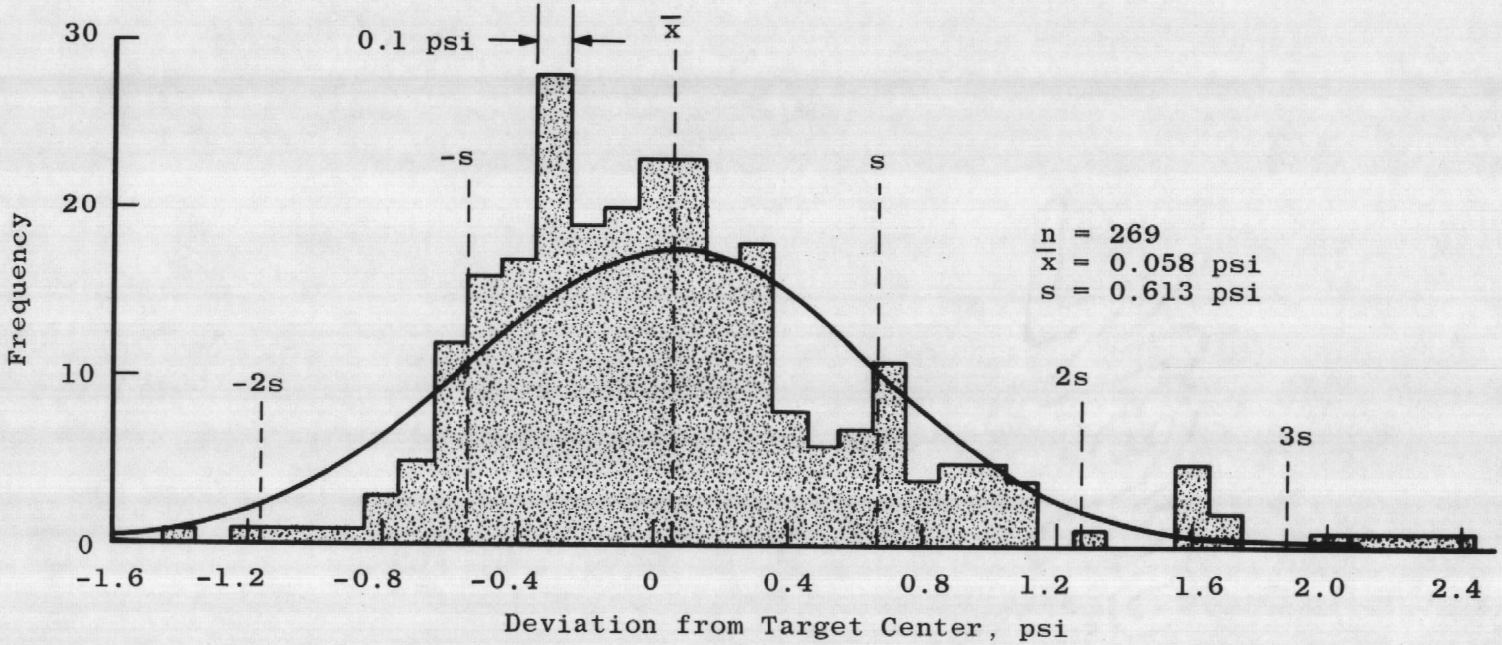
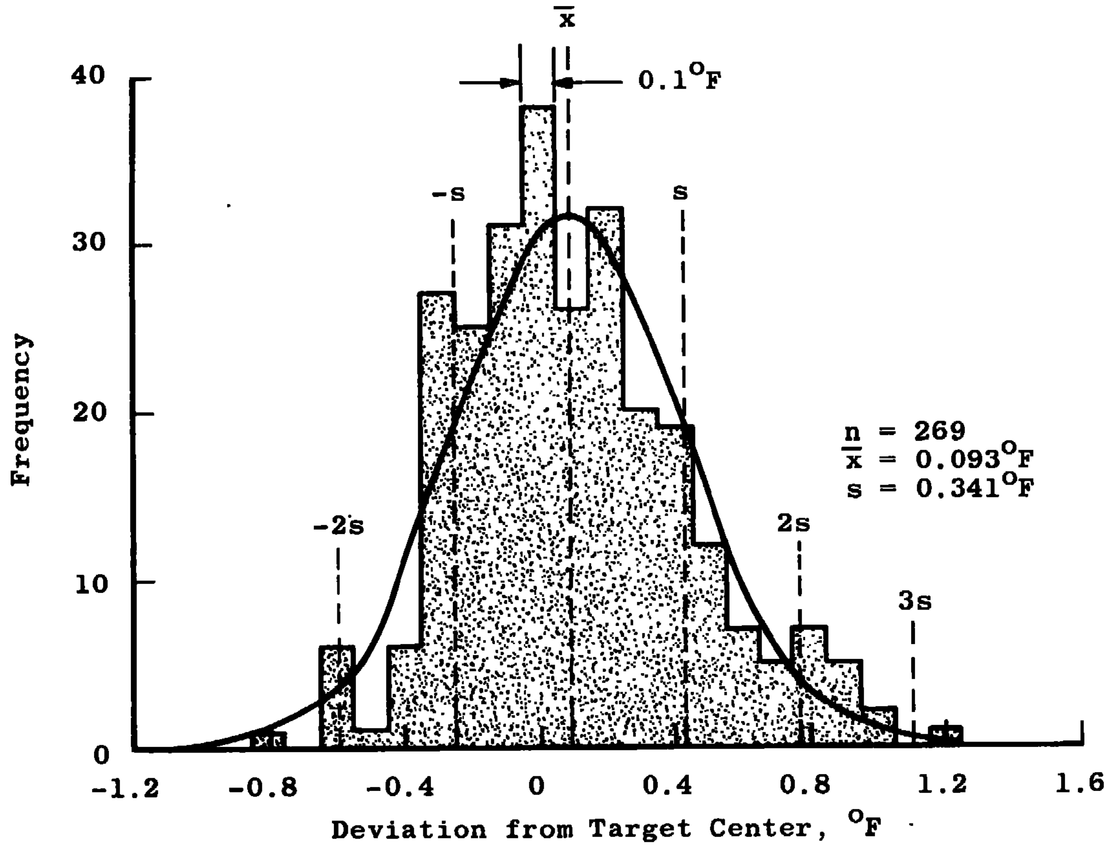


Fig. 7 Typical Engine Component Temperature Conditioning Manifolds



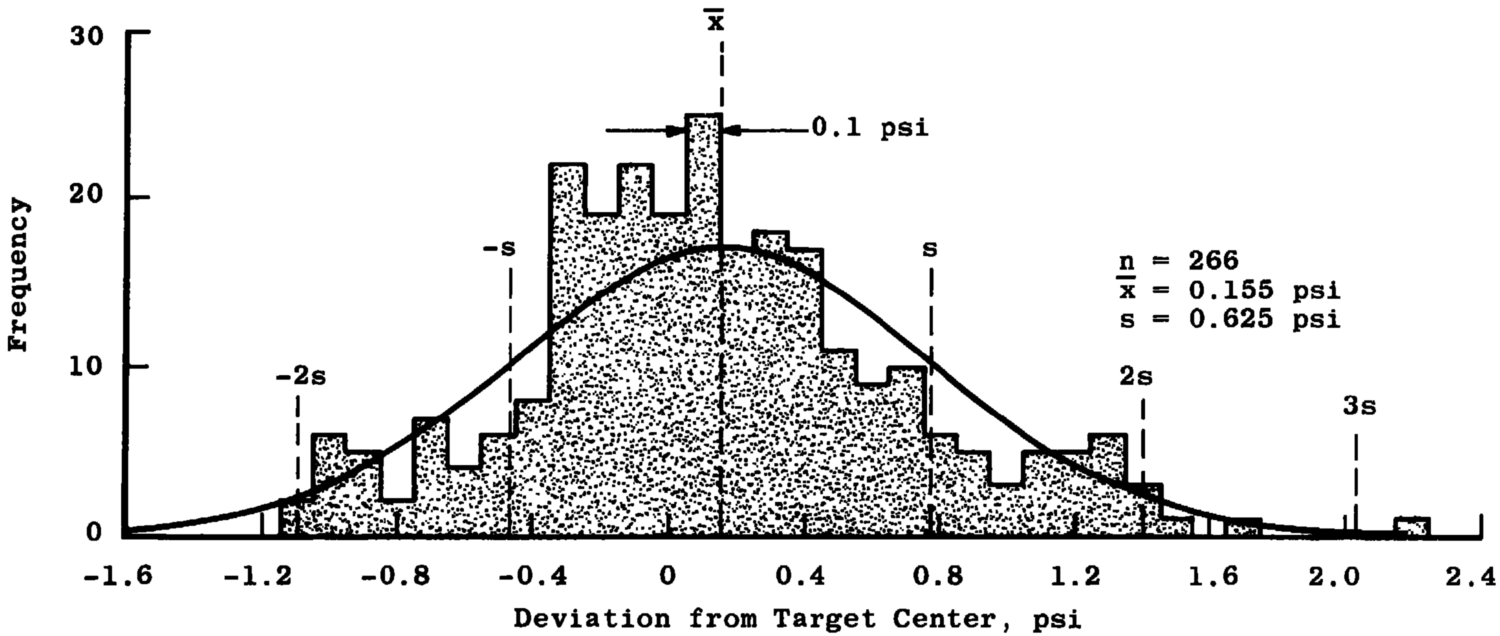
a. Fuel Pump Inlet Pressure

Fig. 8 Parameter Histograms and Normal Distribution Curves



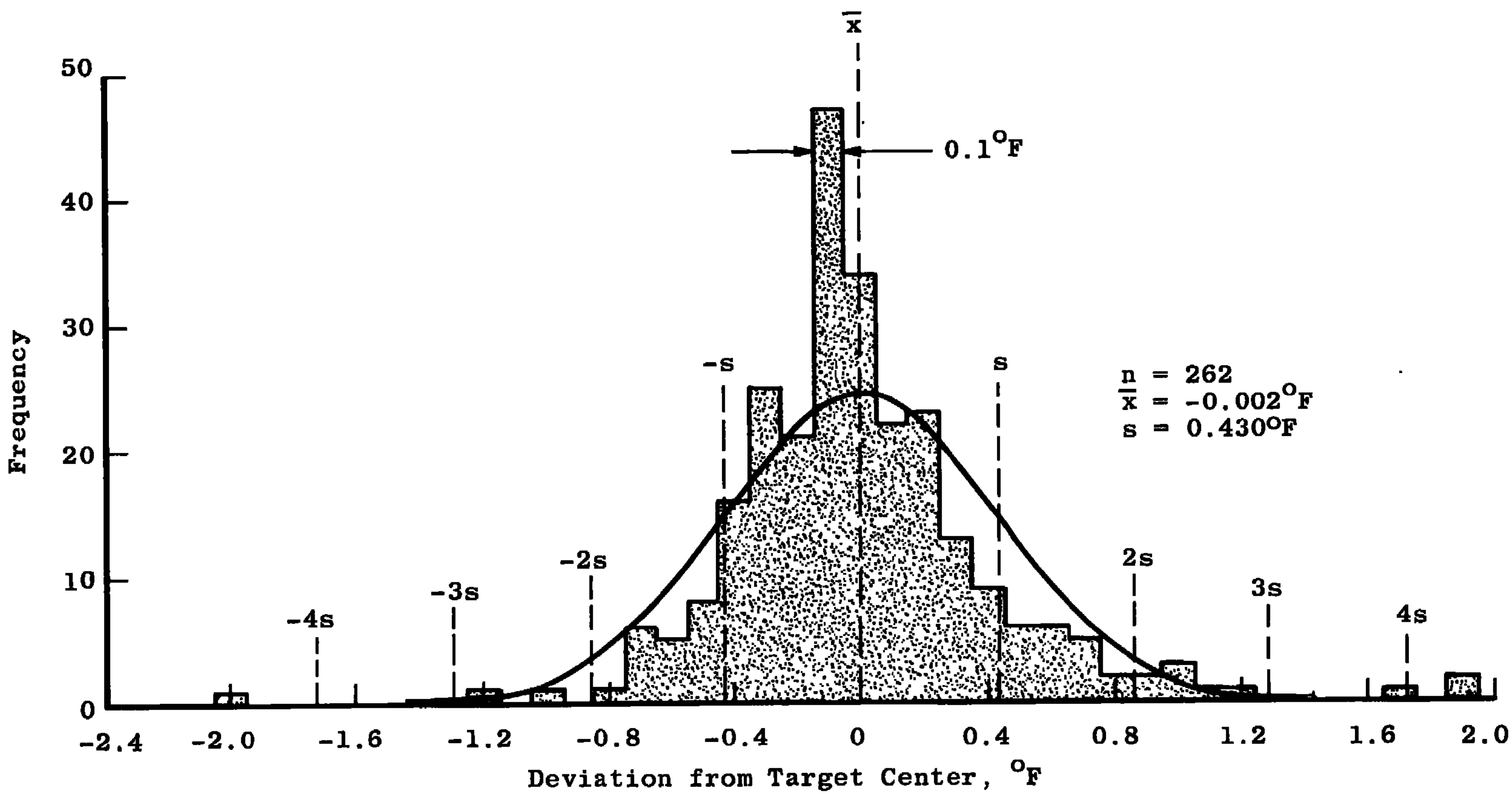
b. Fuel Pump Inlet Temperature

Fig. 8 Continued



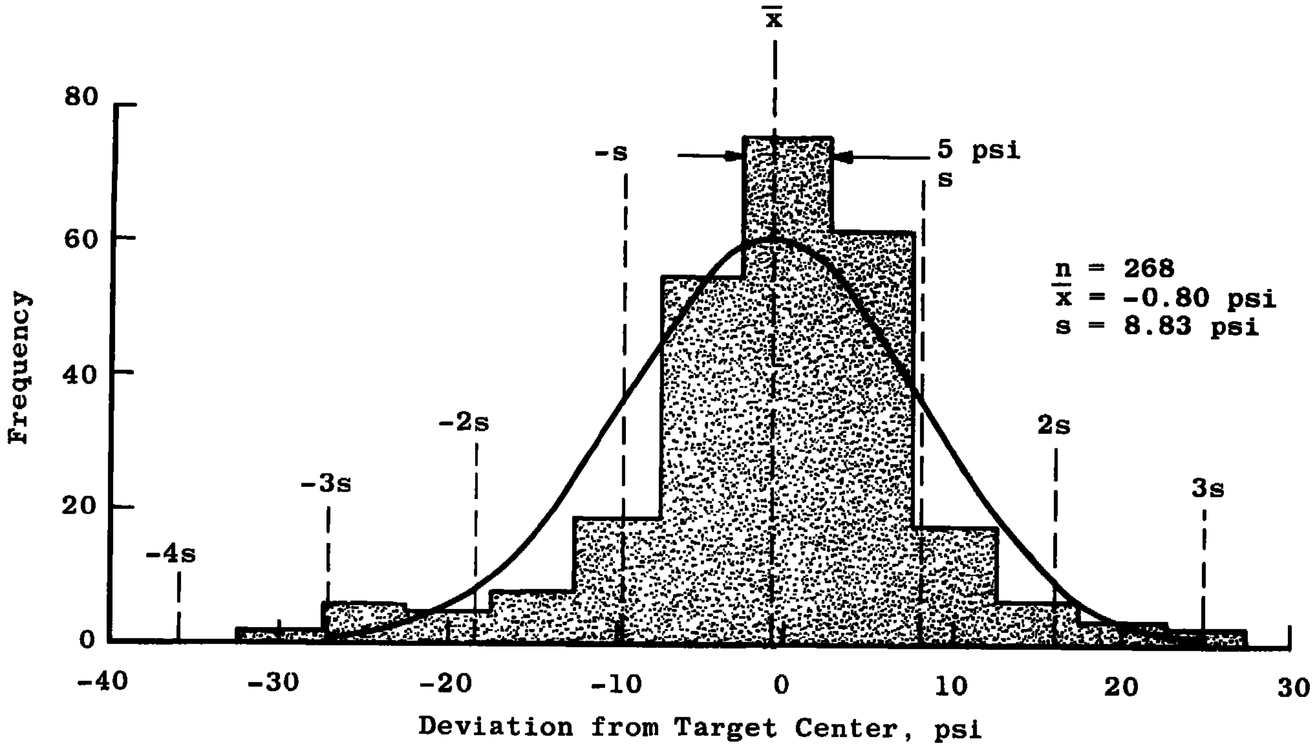
c. Oxidizer Pump Inlet Pressure

Fig. 8 Continued



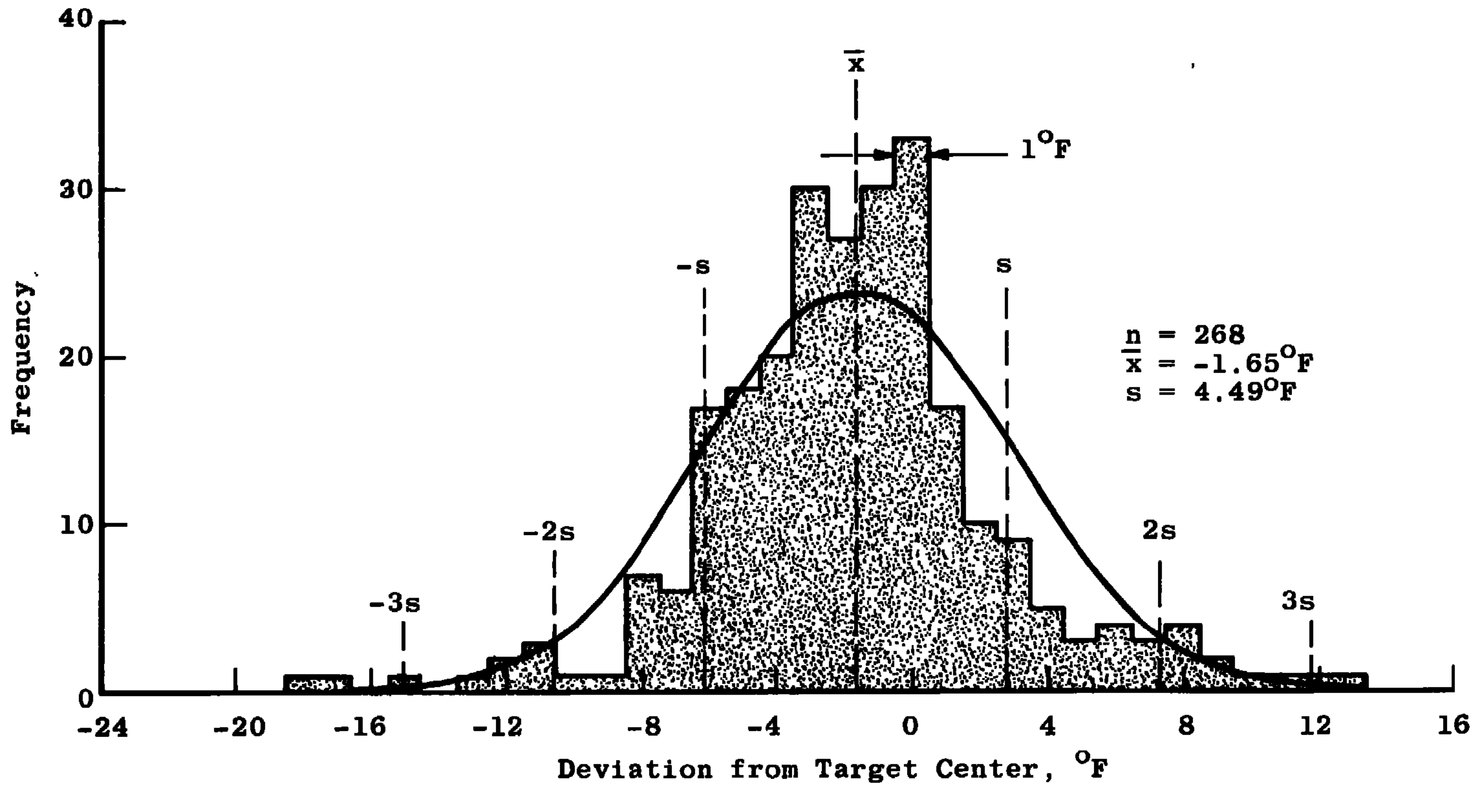
d. Oxidizer Pump Inlet Temperature

Fig. 8 Continued



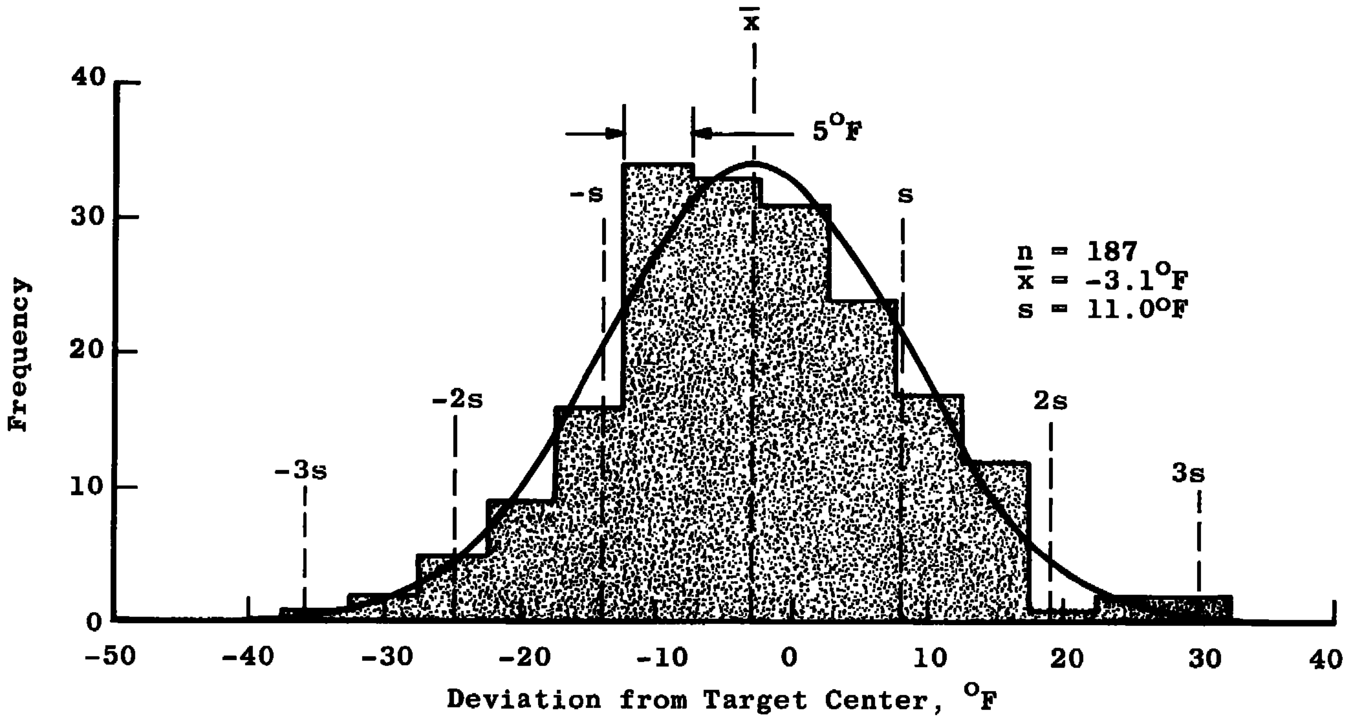
e. Start Tank Pressure

Fig. 8 Continued



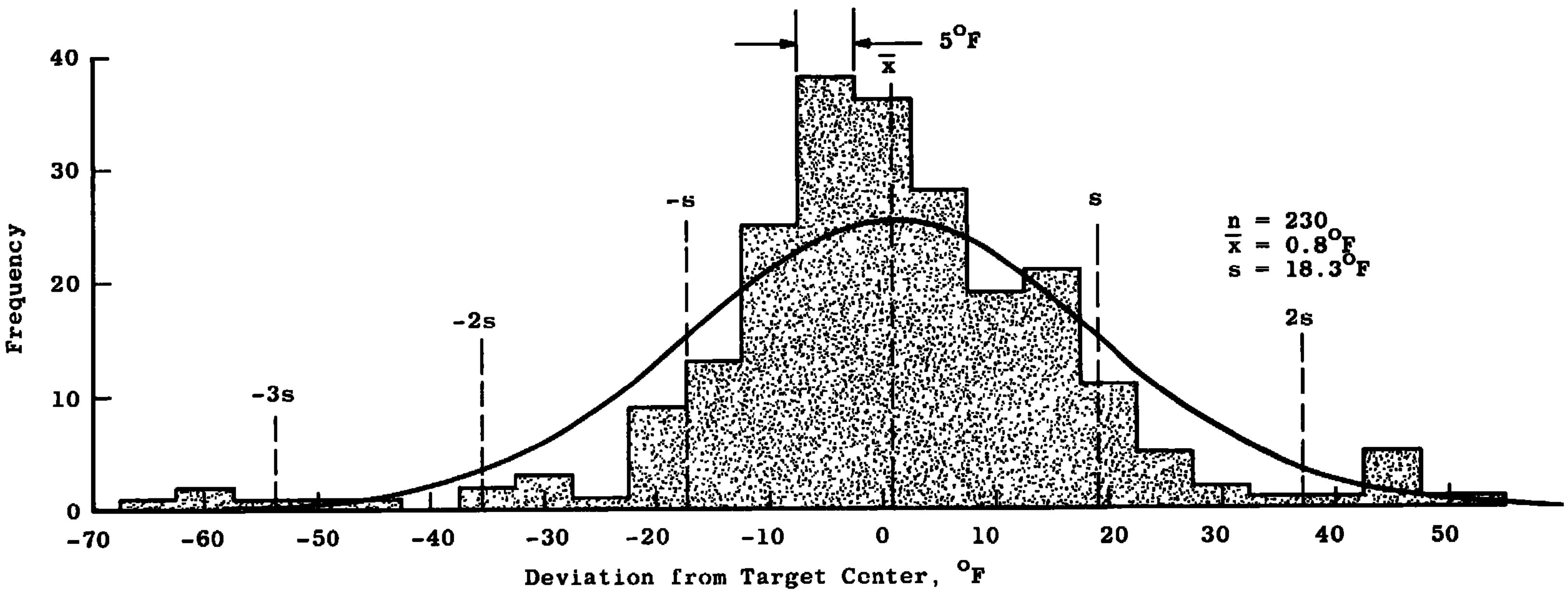
f. Start Tank Temperature

Fig. 8 Continued



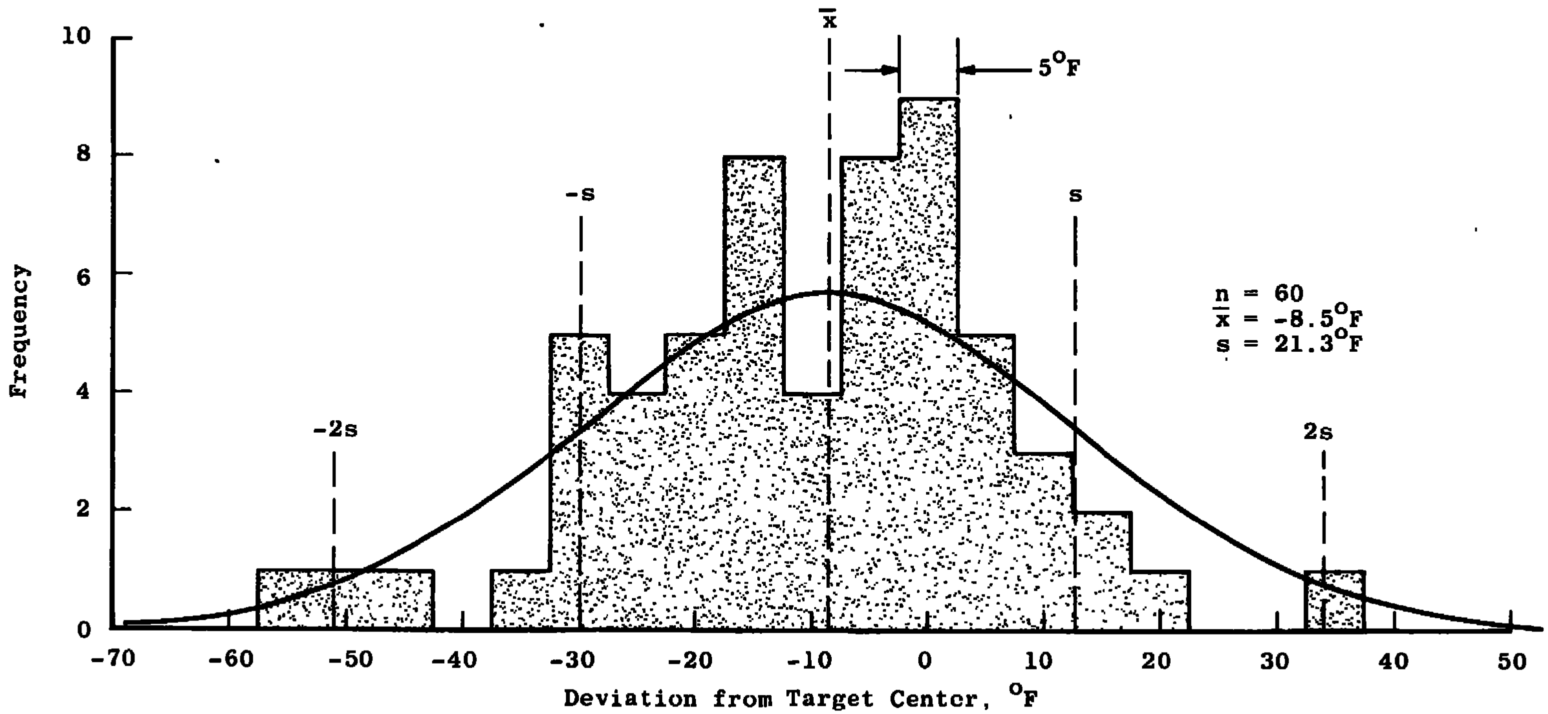
g. Thrust Chamber Throat Temperature

Fig. 8 Continued



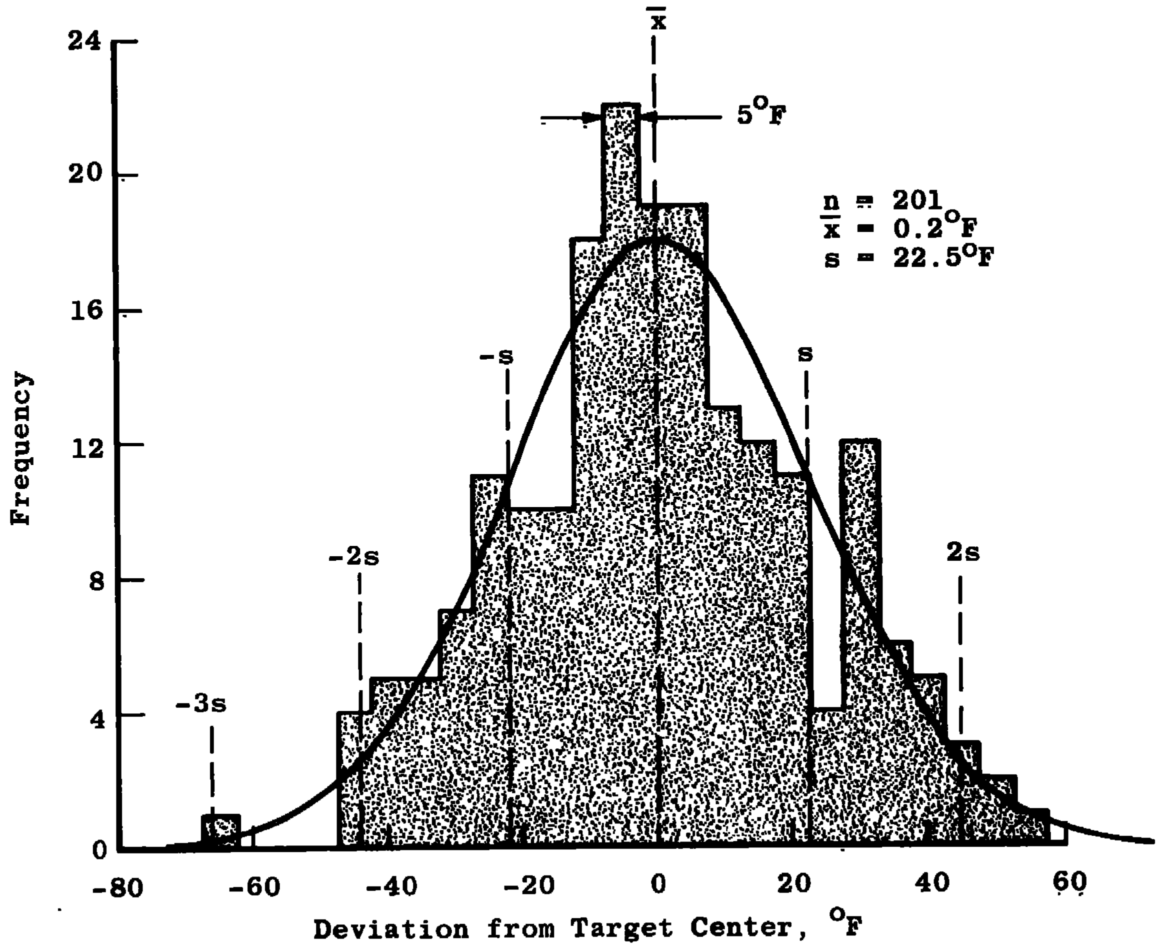
h. Crossover Duct Temperature

Fig. 8 Continued



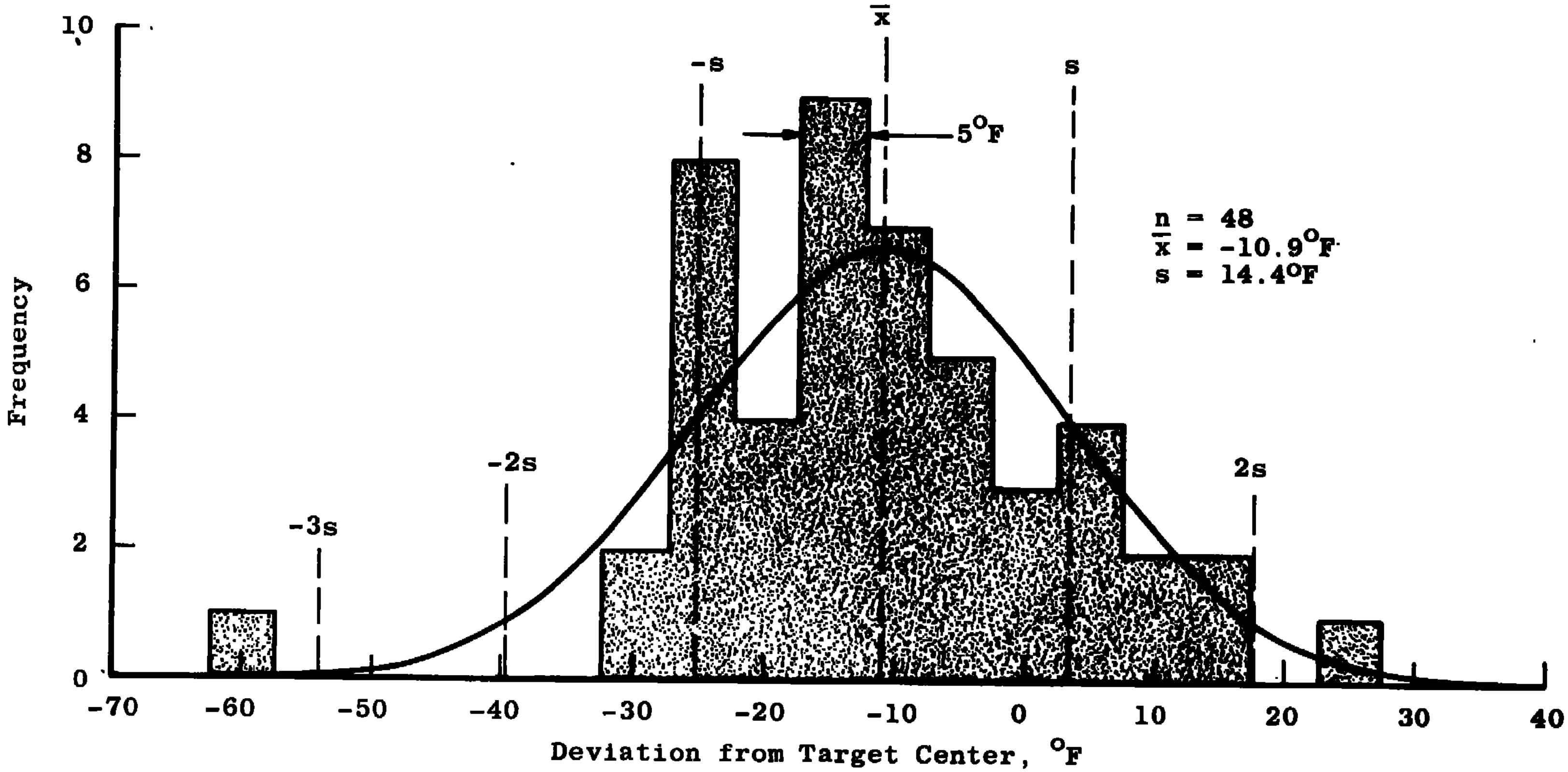
i. Main Oxidizer Valve Closing Control Line Temperature

Fig. 8 Continued



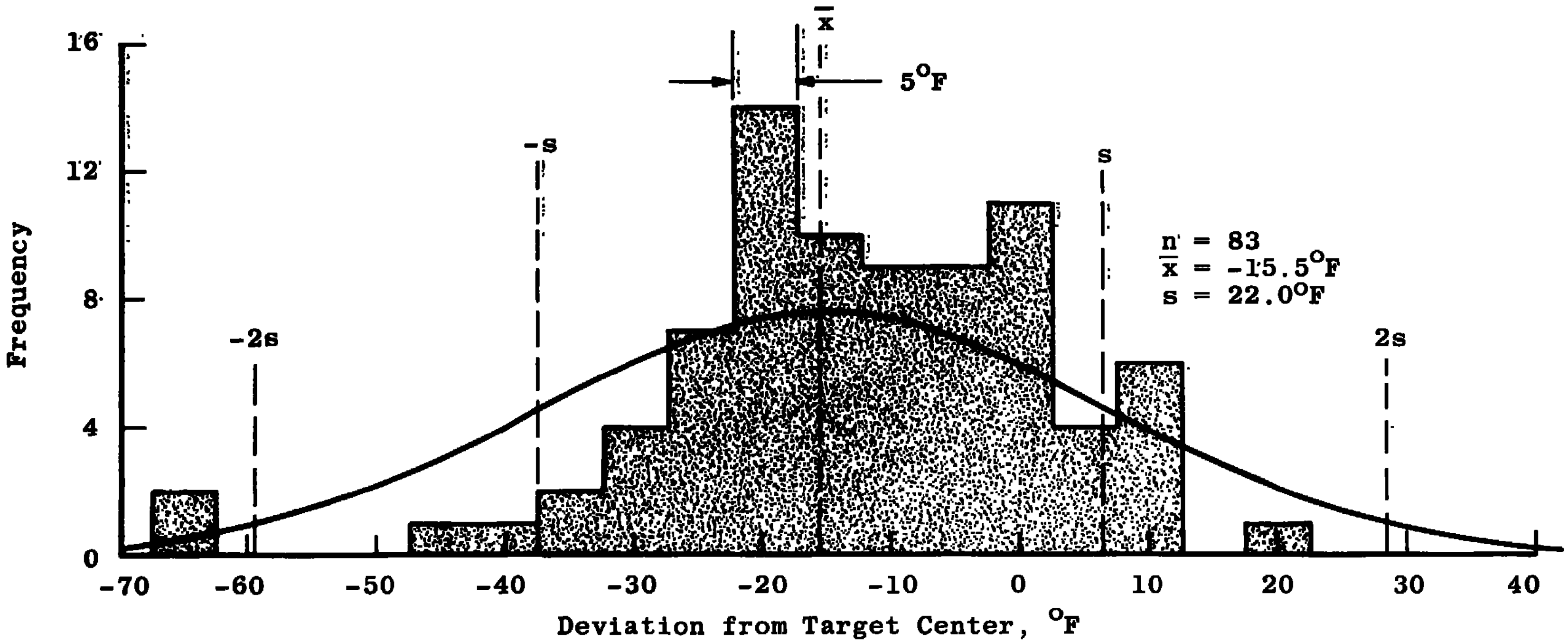
j. Main Oxidizer Valve Actuator Temperature

Fig. 8 Continued



k. Helium Regular Temperature

Fig. 8 Continued



I. Start Tank Discharge Valve Body Temperature

Fig. 8 Concluded

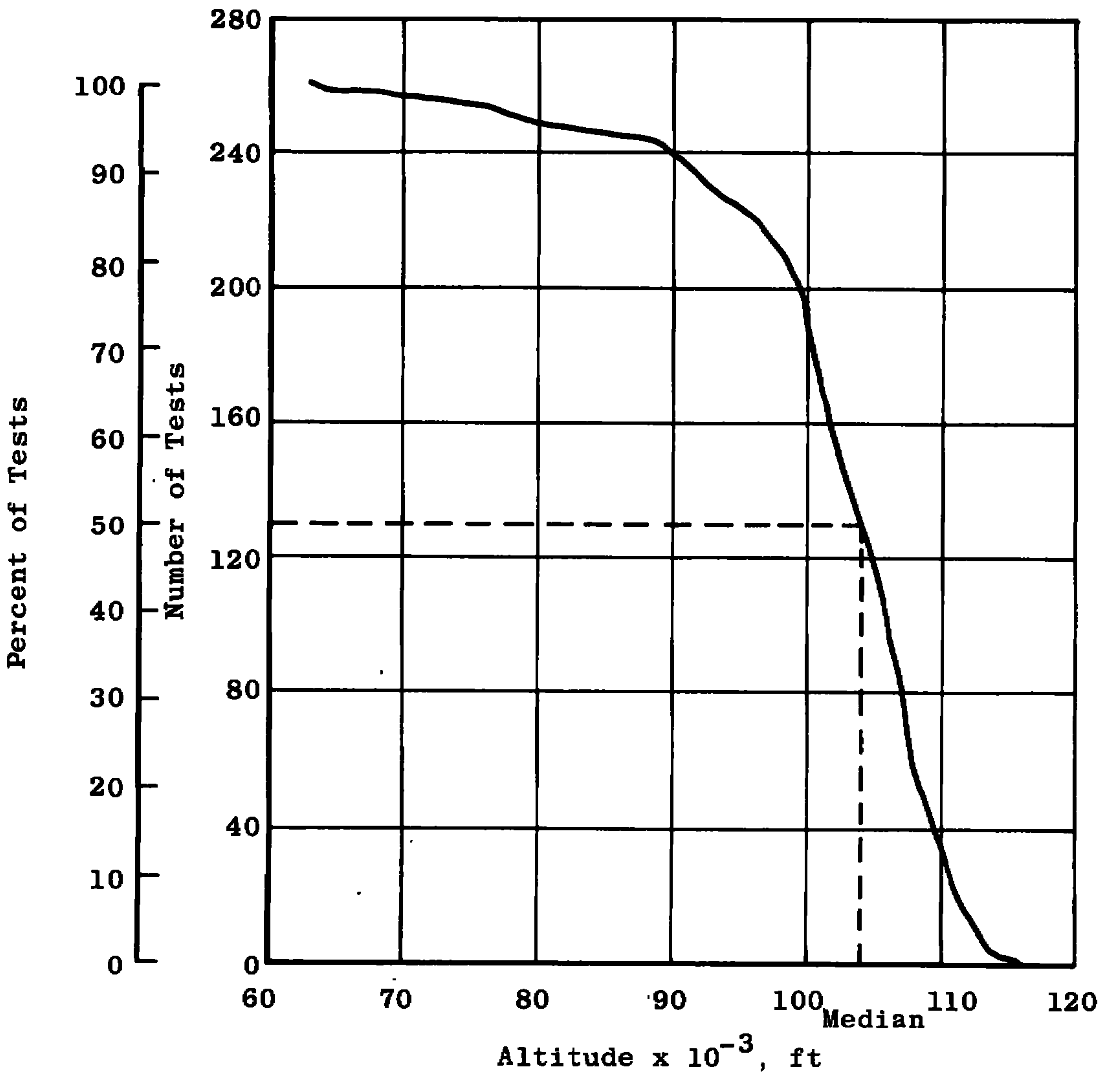


Fig. 9 Engine Ambient Altitude Cumulative Frequency Diagram

TABLE I
TARGETED PARAMETER DATA

Firing Number		1554-02	1554-03	1554-04	1554-05	1554-06	1554-07	1554-08	1554-09A	1554-09B	1554-10A	1554-10B	1554-11A	1554-11B
PFPI, psia	Target	35.5 ± 1.5	35.5 ± 1.5	35.5 ± 1.5	35.5 ± 1.5	35.5 ± 1.5	35.5 ± 1 5	35.5 ± 1.5	33 ± 0.5	37 $^{+0}_{-3}$	33 ± 0 5	37 $^{+0}_{-3}$	34 $^{+3}_{-0}$	34 $^{+3}_{-0}$
	Actual	37.8	37.2	36.2	36.0	36.2	36.3	35.4	33.1	34.9	35.1	35.8	36.4	36.0
TFPI, °F	Target	-419.9 ± 0.4	-419.9 ± 0.4	-419.9 ± 0.4	-419.9 ± 0.4	-419.9 ± 0.4	-420.0 ± 0.4	-419.9 ± 0.4	-420.8 ± 0.4	-421.1 ± 0.4	-420.8 ± 0.4	-421.2 ± 0.4	-419.9 ± 0.4	-421.1 ± 0.4
	Actual	-420.2	-419.9	-420.1	-419 9	-420.5	-419.8	-420.1	-420.9	-421.3	-420.9	-421.2	-420.2	-420.9
POPI, psia	Target	39.5 ± 1.5	39.5 ± 1.5	39.5 ± 1.5	39.5 + 1.5	39.5 ± 1.5	39.5 + 1.5	39.5 ± 1.5	41 ± 0.5	38 $^{+3}_{-0}$	41 ± 0.5	38 $^{+3}_{-0}$	41 $^{+0}_{-3}$	38 $^{+3}_{0}$
	Actual	40.4	39.9	40.1	40.0	40.1	40.6	40.1	41.2	38.6	40.7	38.5	39.2	40.8
TOPI, °F	Target	-295.1 ± 0.4	-295.1 ± 0.4	-295.1 ± 0.4	-295.1 ± 0.4	-295.1 ± 0.4	-295.2 ± 0.4	-295.1 ± 0 4	-295.6 ± 0.4	-290.0 ± 0.4	-295.7 ± 0.4	-290.1 ± 0.4	-296.4 + 0.4	-289.9 ± 0.4
	Actual	-295.1	-295.6	-295.1	-295.3	-296.0	-295.3	-295.0	-295.4	-289.9	-296.0	-289.2	-296.1	-289.7
PFST, psia	Target	1250 ± 25	1250 ± 25	1250 ± 25	1325 ± 25	1325 + 25	1325 ± 25	1325 ± 25	1250 ± 25	1325 ± 25	1350 ± 25	1350 ± 25	1375 ± 25	1350 ± 25
	Actual	1241	1248	1265	1324	1332	1323	1314	1264	1350	1353	1362	1362	1362
TFST, °F	Target	-250 ± 25	-250 ± 25	-250 ± 25	-200 ± 25	-200 ± 25	-200 ± 25	-170 ± 30	-200 ± 25	-200 ± 20	-200 ± 25	-200 ± 25	-200 ± 25	-200 $^{+25}_{-0}$
	Actual	-244	-260	-251	-199	-195	-204	-173	-187	-190	-200	-211	-198	-205
TTC, °F	Target	---	---	-225 ± 25	-225 + 25	-150 ± 25	-100 + 15	-220 ± 10	-220 ± 10	---	-220 ± 10	---	-165 ± 10	---
	Actual	---	---	-239	-234	-171	-90	-226	-217	---	-213	---	-176	--
TFTD, °F	Target	---	---	---	---	- -	---	---	---	---	---	---	-----	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
TSOVAL, °F	Target	---	---	---	---	---	---	---	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
TSOVC, °F	Target	---	---	---	---	---	---	---	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
TBHR, °F	Target	---	---	---	---	---	---	---	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
TSTDVOC, °F	Target	---	---	---	---	---	---	---	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
Altitude, ft	Target	100,000	100,000	100,000	---	---	100,000	100,000	---	100,000	100,000	100,000	100,000	100,000
	Actual	65,600	77,300	67,200	---	---	75,300	75,600	---	92,300	105,700	109,200	109,000	103,900

TABLE I (Continued)

Firing Number		1554-11C	1554-12A	1554-12B	1554-13A	1554-13B	1554-14	1554-15A	1554-15B	1554-15C	1554-16	1554-17A	1554-17B	1554-17C
PFPI, psia	Target	---	34^{+3}_{-0}	37^{+0}_{-3}	37^{+0}_{-3}	36.5 ± 1.5	34^{+3}_{-0}	36.5 ± 1.5	36.5 ± 1.5	37^{+0}_{3}	37^{+0}_{-2}	40 ± 1.5	40 ± 1.5	30^{+3}_{-0}
	Actual	---	34.4	36.2	36.2	36.1	35.0	36 6	36.1	35.3	35.4	40.4	39.9	32.5
TFPI, °F	Target	---	-421.5 ± 0.4	-420.0 ± 0.4	-420.0 ± 0.4	-421 0 ± 0.4	-421.6 ± 0.4	-421.0 ± 0.4	-421.0 + 0.4	-421.0 ± 0.4	-423.0 ± 0.4	-421.8 ± 0 4	-421.8 ± 0.4	-422.0 ± 0.4
	Actual	---	-420.9	-420.1	-419.9	421.2	-421.9	-420.8	-420.5	-420.3	-422.1	-422.4	-421.5	-422.0
POPI, psia	Target	---	38^{+3}_{-0}	38^{+3}_{-0}	38^{+3}_{-0}	38.5^{+3}_{-0}	38^{+3}_{-0}	41.5 + 1.5	41.5 ± 1.5	38^{+3}_{-0}	41^{+0}_{-2}	45 ± 1.5	45 ± 1.5	45 ± 1.0
	Actual	---	40.7	40.8	40.6	41.2	41.7	42.9	42.3	40.5	38.9	46 3	45.6	45.7
TOPI, °F	Target	---	-290.0 ± 0.4	-290.0 ± 0.4	-296.4 ± 0.4	-289.2 ± 0.4	-290.1 ± 0.4	-291 1 + 0.4	-291.1 ± 0.4	-296.5 ± 0.4	-295.0 ± 0.4	-293.0 ± 0.4	-293.0 ± 0.4	-293.0 ± 0.4
	Actual	--	-290.0	-289.8	-296.1	-291.2	-290.6	-291.2	-290.7	-296.6	-295.7	-293.2	-293.3	-293.1
PFST, psia	Target	---	1250^{+25}_{-0}	1375^{+0}_{-25}	1375^{+25}_{-0}	1350^{+0}_{-25}	1250^{+25}_{-0}	1350^{+25}_{-0}	1350^{+25}_{-0}	1375^{+25}_{-0}	1350^{+25}_{-0}	1410 ± 10	1380 ± 10	1410 ± 10
	Actual	---	1259	1369	1364	1359	1269	1362	1361	1370	1369	1386	1372	1385
TFST, °F	Target	--	-140^{+0}_{-30}	-200^{+30}_{-0}	-170^{+0}_{-30}	-200^{+0}_{-25}	-140^{+0}_{-30}	-200^{+0}_{-25}	-200^{+0}_{-25}	-170^{+0}_{-30}	-200^{+0}_{-25}	-200 ± 10	-225 ± 10	200 ± 10
	Actual	---	-161	-190	193	-218	-146	-214	-210	-198	-216	-210	-230	-201
TTC, °F	Target	--	-88 ± 10	-215 ± 10	-215 ± 10	---	---	-	---	-215 ± 10	---	-200 ± 10	---	-80 ± 10
	Actual	---	-110	-215	-210	---	---	---	---	-224	---	-211	---	-86
TFTD, °F	Target	---	---	---	---	---	-	---	---	- -	---	-75^{+0}_{-25}	125^{+0}_{-25}	-75^{+0}_{-25}
	Actual	---	---	---	---	---	-	---	---	---	---	-52	160	-45
TSOVAL, °F	Target	---	---	---	---	---	---	---	--	---	---	---	---	---
	Actual	---	---	---	---	---	-	---	---	---	---	---	---	---
TSOVC, °F	Target	---	---	---	---	---	---	-	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	--	---	---	---	---	---	---
TBHR, °F	Target	---	---	---	---	---	---	---	--	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	-	---	---	---	---	---
TSTDVOC, °F	Target	---	---	---	---	---	---	---	---	---	--	---	---	---
	Actual	---	--	---	---	---	---	---	---	---	---	---	---	---
Altitude, ft	Target	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
	Actual	108,700	96,300	105,700	100,400	107,700	103,100	105,700	110,700	110,200	111,200	92,500	109,000	107,000

TABLE I (Continued)

Firing Number		1554-18	1554-19	1554-20	1554-21A	1554-21B	1554-21C	1554-22A	1554-22B	1554-23A	1554-23C	1554-23D	1554-23E	1554-24A
PFPI, psia	Target	30^{+3}_{-0}	30^{+3}_{-0}	31 ± 1	41 ± 1	35 ± 1	35 ± 1	35 ± 1	37 ± 1	37^{+1}_{-0}	35 ± 1	37 ± 1	30^{+1}_{-0}	37^{+1}_{-0}
	Actual	31.6	31.8	30.4	41.0	34.5	38.0	35.9	36.9	37.9	35.1	36.9	30.4	37.8
TFPI, °F	Target	-422.0 ± 0.4	-421.2 ± 0.4	-420.4 ± 0.4	-422.2 ± 0.4	-420.4 ± 0.4	-420.4 ± 0.4	-420.4 ± 0.4	-421.1 ± 0.4	-421.1 ± 0.4	-420.4 ± 0.4	-421.4 ± 0.4	-421.0 + 0.4	-422.2 ± 0.4
	Actual	-422.1	-421.1	-420.7	-421.8	-420.7	-420.7	-420.2	-420.2	-421.2	-419.8	-421.1	-421.1	-421.5
POPI, psia	Target	35^{+3}_{-0}	---	38 ± 1	41 ± 1	41 ± 1	41 ± 1	41 ± 1	---	38^{+0}_{-1}	41 ± 1	41 ± 1	41^{+1}_{-0}	38 ± 1
	Actual	37.6	---	38.6	41.3	41.1	40.9	40.8	---	37.4	41.4	41.8	42.0	38.0
TOPI, °F	Target	-297.4 ± 0.4	---	-290.4 ± 0.4	-295.3 ± 0.4	-294.9 ± 0.4	-295.6 ± 0.4	-295.6 ± 0.4	-294.9 ± 0.4	-290.4 ± 0.4	-294.0 ± 0.4	-294.9 ± 0.4	-294.9 ± 0.4	-295.3 + 0.4
	Actual	-296.4	---	-290.8	-295.7	-295.0	-295.9	-296.0	-294.3	-290.1	-293.5	-294.2	-294.9	-295.3
PFST, psia	Target	1250 ± 10	1250 ± 10	1250 ± 10	1270 ± 10	1380 ± 10	1400 ± 10	1250 ± 10	1300 ± 10	1250 ± 10	1250 ± 10	1380 ± 10	1380 ± 10	1250 ± 10
	Actual	1249	1249	1243	1285	1385	1410	1252	1319	1263	1252	1384	1387	1255
TFST, °F	Target	-140 ± 10	-140 ± 10	-140 ± 10	-170 ± 10	-225 ± 10	-200 ± 10	-140 ± 10	-210 + 10	-140 ± 10	-140 ± 10	-225 ± 10	-225 ± 10	-140 ± 10
	Actual	-146	-146	-141	-170	-216	-203	-133	-207	-145	-145	-222	-227	-147
TTC, °F	Target	---	-200 ± 10	---	-220 ± 10	---	---	---	---	---	---	---	---	---
	Actual	---	-231	---	-197	---	---	-	---	---	---	---	---	---
TFTD, °F	Target	-50^{+25}_{-0}	-75^{+0}_{-25}	-50^{+25}_{-0}	-75 ± 15	125 ± 10	-100^{+25}_{-10}	-100^{+25}_{-10}	125 ± 10	-100 ± 15	-100 ± 15	125 ± 10	---	-100 ± 15
	Actual	-41	-56	-42	-53	66	-93	-55	116	-107	-93	126	---	-102
TSOVAL, °F	Target	-100^{+50}_{-0}	-75^{+0}_{-25}	-50^{+25}_{-0}	-150^{+25}_{-0}	-150^{+25}_{-0}	-100^{+25}_{-0}	-20^{+0}_{-25}	-150^{+25}_{-0}	-20 ± 10	50^{+0}_{-25}	-150^{+25}_{-0}	---	-50 ± 25
	Actual	-14	-69	-59	-154	-158	-138	-24	-170	-42	-9	-122	---	-53
TSOVC, °F	Target	---	---	---	---	---	---	---	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
TBHR, °F	Target	---	-75^{+0}_{-25}	-50^{+25}_{-0}	-150^{+25}_{-0}	-150^{+25}_{-0}	-100^{+25}_{-0}	-20^{+0}_{-25}	-150^{+25}_{-0}	-20 ± 10	50^{+0}_{-25}	-150^{+25}_{-0}	---	-50 ± 25
	Actual	---	-86	-51	-145	-147	-99	20	-159	-34	-21	-112	---	-73
TSTDVOC, °F	Target	---	---	-	---	---	---	---	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
Altitude, ft	Target	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
	Actual	99,100	105,000	99,600	95,400	104,800	104,800	97,200	99,800	104,300	106,700	109,600	108,700	105,000

TABLE I (Continued)

Firing Number		1554-24B	1554-24C	1554-24D	1554-25A	1554-25B	1554-25C	1554-25D	1554-26A	1554-26B	1554-26C	1554-26D	1554-27A	1554-27B
PFPI, psia	Target	37 ± 1	35 ± 1	30^{+1}_{-0}	35 ± 1	37 ± 1	35 ± 1	37 ± 1	35 ± 1	35 ± 1	35 ± 1	37 ± 1	36^{+0}_{-1}	34 ± 1
	Actual	37.2	35.7	31.2	35.6	37.1	35.4	37.6	35.6	34.7	35.8	36.7	34.7	33.5
TFPI, °F	Target	-422.3 ± 0.4	-420.4 ± 0.4	-421.0 ± 0.4	-420.0 ± 0.4	-420.0 ± 0.4	-420.0 ± 0.4	-420.0 ± 0.4	-421.1 ± 0.4	-421.1 ± 0.4	-421.1 ± 0.4	-419.6 ± 0.4	-422.1 ± 0.4	-421.4 ± 0.4
	Actual	-421.6	-420.7	-420.7	-420.0	-419.7	-418.8	-419.9	-421.4	-420.9	-421.3	-419.4	-421.5	-421.3
POPI, psia	Target	41 ± 1	38 ± 1	41 ± 1	41 ± 1	41 ± 1	41 ± 1	41 ± 1	40 ± 1	40 ± 1	40 ± 1	41 ± 1	38^{+0}_{-1}	35^{+1}_{-0}
	Actual	41.1	38.5	41.4	41.2	40.9	41.9	41.4	40.0	40.4	40.3	40.0	37.5	35.2
TOPI, °F	Target	-295.3 ± 0.4	-295.3 ± 0.4	-295.3 ± 0.4	-295.3 ± 0.4	-295.3 ± 0.4	-295.3 ± 0.4	-295.3 ± 0.4	-293.0 ± 0.4	-293.0 ± 0.4	-293.0 ± 0.4	-295.6 ± 0.4	-295.2 ± 0.4	-294.0 ± 0.4
	Actual	-295.7	-295.8	-295.5	-295.6	-295.6	-295.8	-295.4	-293.7	-293.4	-293.1	-295.4	-295.7	-294.2
PFST, psia	Target	1385 ± 10	1250 ± 10	1385 ± 10	1380 ± 10	1300 ± 10	1250 ± 10	1315 ± 10	1325 ± 10	1300 ± 10	1325 ± 10	1300 ± 10	1300 ± 10	1250 ± 10
	Actual	1390	1244	1384	1376	1292	1247	1319	1327	1303	1330	1306	1296	1242
TFST, °F	Target	-225 ± 10	-140 ± 10	-225 ± 10	-225 ± 10	-210 ± 10	-140 ± 10	-225 ± 10	-170 ± 10	-190 ± 10	-170 ± 10	210 ± 10	-300 ± 10	-250 ± 10
	Actual	-228	-145	-231	224	207	-141	-217	-173	-194	-179	-215	-304	-253
TTC, °F	Target	---	---	---	---	---	---	---	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
TFTD, °F	Target	125 ± 10	-100 ± 15	125 ± 10	---	125^{+15}_{-0}	---	-165^{+15}_{-0}	-75 ± 15	50 ± 25	-75 ± 15	125^{+15}_{-0}	---	-50^{+0}_{-5}
	Actual	104	-133	115	---	120	---	160	-28	-65	-22	-130	---	-44
TSOVAL, °F	Target	-150 ± 25	-20 ± 10	-150^{+25}_{-10}	-150^{+25}_{-10}	-150^{+25}_{-10}	-150^{+25}_{-10}	-150^{+25}_{-10}	-75 ± 15	-80 ± 15	-75 ± 15	-150^{+25}_{-0}	-100 ± 10	-50^{+10}_{-5}
	Actual	-164	-19	-131	-140	-168	-166	-133	-71	-92	-80	-151	-120	-85
TSOVC, °F	Target	---	--	---	---	---	---	---	---	---	---	---	-225 ± 10	-160 ± 10
	Actual	---	---	---	---	---	---	---	---	---	---	---	-234	-187
TBHR, °F	Target	-150 ± 25	-20 ± 10	150 ± 25	-150^{+25}_{-0}	-150^{+25}_{-0}	-150^{+25}_{-0}	-150^{+25}_{-0}	-75 ± 15	-80 ± 15	-75 ± 15	-150^{+25}_{-10}	-100 ± 10	-50^{+10}_{-5}
	Actual	-155	-31	-151	-150	-156	-156	-145	-70	86	-64	-153	-123	-73
TSTDVOC, °F	Target	---	---	---	---	-	---	---	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
Altitude, ft	Target	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
	Actual	110,700	109,600	110,200	101,700	104,800	104,800	106,700	108,600	110,700	103,200	103,200	106,700	106,700

TABLE I (Continued)

Firing Number		1554-27C	1554-27D	1554-28A	1554-28B	1554-28C	1554-29A	1554-29B	1554-29C	1554-29D	1554-30A	1801-01A	1801 01B	1801-01C
PFPI, psia	Target	30^{+1}_{-0}	34 ± 1	41 ± 1	36^{+0}_{-1}	30^{+1}_{-0}	28^{+1}_{-0}	28^{+1}_{-0}	28^{+1}_{-0}	28^{+1}_{-0}	28^{+1}_{-0}	28^{+1}_{-0}	28^{+1}_{-0}	28^{+1}_{-0}
	Actual	30.2	32.9	41.0	36.1	29.9	28.4	27.8	28.6	28.5	28.5	29.0	28.1	28.5
TFPI, °F	Target	-420.4 ± 0.4	-421.4 ± 0.4	-422.2 + 0.4	-422.1 ± 0.4	-420.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4
	Actual	-420.1	-421.1	-421.8	-421.9	-420.1	-421.3	-421.6	-421.6	-421.6	-421.5	-420.8	-421.2	-421.6
POPI, psia	Target	39^{+0}_{-1}	35 ± 1	41 ± 1	38^{+0}_{-1}	39^{+0}_{-1}	35 ± 1	35 ± 1	41^{+0}_{-1}	41^{+0}_{-1}	41^{+0}_{-1}	41^{+0}_{-1}	41^{+0}_{-1}	41^{+0}_{-1}
	Actual	38.1	35.4	41.2	37.4	38.7	35.0	34.0	40.3	40.1	40.2	40.4	40.4	40.3
TOPI, °F	Target	-295.2 ± 0.4	-294.0 ± 0.4	295.3 ± 0.4	-295.2 ± 0.4	-295.2 ± 0.4	-294.0 ± 0.4	-294.0 ± 0.4	-295.2 ± 0.4	-295.2 ± 0.4	-295.2 ± 0.4	-295.2 ± 0.4	-295.2 ± 0.4	-295.2 ± 0.4
	Actual	-295.3	-293.9	-295.4	-294.5	-295.1	-294.1	-294.6	-295.4	-295.1	-295.0	-295.6	-294.7	-295.8
PFST, psia	Target	1300 ± 10	1200 ± 10	1270 ± 10	1300 ± 10	1300 ± 10	1200 ± 10	1200 ± 10	1300 ± 10	1200 ± 10	1300 + 10	1300 ± 10	1300 ± 10	1300 ± 10
	Actual	1290	1194	1262	1308	1310	1199	1196	1306	1204	1303	1307	1293	1298
TFST, °F	Target	-300 ± 10	-200 ± 10	-170 ± 10	-300 ± 10	-300 ± 10	-200 ± 10	-200 ± 10	-300 + 10	-300 ± 10	300 ± 10	-300 ± 10	-300 ± 10	-300 ± 10
	Actual	-303	-206	-178	-312	-315	-197	-212	-311	-306	-311	-304	-306	-308
TTC, °F	Target	---	---	---	-150 ± 10	-260 ± 10	-260 ± 15	-150 ± 15	-150 ± 15	-150 ± 15	-260 + 15	-150 ± 15	260 ± 15	-260 ± 15
	Actual	---	---	---	-169	-249	-258	-174	-176	-177	-260	-163	-257	-270
TFTD, °F	Target	0 + 10	0 ± 10	-60 ± 10	0^{+0}_{-10}	0^{+0}_{-10}	-100 ± 25	-100 ± 25	0^{+25}_{-10}	0^{+25}_{-10}	-100 ± 25	0^{+15}_{-10}	0^{+15}_{-10}	-100 ± 15
	Actual	-1	-61	-38	13	+11	-86	-79	14	+24	-90	-19	-17	-80
TSOVAL, °F	Target	-100 ± 10	0 ± 10	-35 ± 10	-80 ± 10	-80 ± 10	0 ± 10	0 ± 10	-80 ± 10	-80 ± 10	0 ± 10	-85 ± 10	-85 ± 10	-85 ± 10
	Actual	-130	-28	-38	-85	-92	+1	-23	-110	-107	-1	-139	-102	-98
TSOVC, °F	Target	-225 ± 10	-140 ± 15	-112^{+0}_{-15}	-170^{+0}_{-10}	-170^{+0}_{-10}	-140 ± 10	-140 ± 10	-170 ± 10	-170 ± 10	-150 ± 10	-150 ± 10	-150 ± 10	-150 ± 10
	Actual	-206	-148	-165	-146	-157	-150	-160	-151	-155	-161	-167	-152	-148
TBHR, °F	Target	-100 ± 10	0 ± 10	-55 ± 5	-75 ± 10	-75 ± 10	0 ± 20	0 ± 20	-80 ± 20	-80 ± 20	0 ± 20	-85 ± 10	-85 + 10	-85 ± 10
	Actual	-110	-13	-43	-62	-72	-14	+6	-95	-92	-24	-110	-115	-109
TSTDVOC, °F	Target	---	---	---	---	---	---	---	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
Altitude, ft	Target	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
	Actual	104,800	97,000	106,700	108,600	95,400	97,700	99,000	100,300	99,000	102,000	97,000	105,600	108,400

TABLE I (Continued)

Firing Number		1801-01D	1801-02A	1801-02B	1801-02C	1801-02D	1801-02E	1801-03A	1801-03B	1801-04A	1801-04B	1801-04C	1801-04E
PFPI, psia	Target	28^{+1}_{-0}	28^{+1}_{-0}	37 ± 1	28^{+1}_{-0}	37 ± 1	46 ± 1	28 ± 1	28 + 1	28 ± 1	28 ± 1	28 ± 1	28 ± 1
	Actual	29.0	28.3	36.5	27.8	35.8	43.0	29.6	28.3	30.0	27.6	28.3	30.2
TFPI, °F	Target	-421 4 ± 0.4	-420.4 ± 0.4	-420.0 ± 0.4	-420.4 ± 0.4	-420.0 ± 0.4	-421.1 ± 0.4	-420.4 ± 0.4	-421.5 ± 0.4	-420.4 ± 0.4	421.4 ± 0.4	-420.4 + 0.4	-420.4 ± 0.4
	Actual	-421.4	-420.4	-420.6	-420.3	-419 7	-420.2	-420.6	-420.6	-420.1	-420.5	-420.3	-420.7
POPI, psia	Target	41^{+0}_{-1}	48 + 1	41 ± 1	48 ± 1	41 ± 1	35 + 1	48 ± 1	48 ± 1	48 + 1	48 ± 1	35 ± 1	48 ± 1
	Actual	40.8	47.7	40.1	47.9	40.3	35.2	48.6	47.8	48.1	47.9	35.1	48.4
TOPI, °F	Target	-295.2 ± 0.4	-295.3 ± 0.4	-295.3 ± 0.4	-295.3 + 0.4	-295.3 ± 0.4	-290.4 ± 0.4	-295.3 ± 0.4	-295.3 ± 0.4	-295.3 ± 0.4	-295.3 ± 0.4	-294.0 ± 0.4	-295.3 ± 0.4
	Actual	295.7	-295.8	-295.7	-296.0	-295.3	-290.2	-294.6	-294.3	-296.5	-295.5	-294.6	-296.0
PFST, psia	Target	1300 + 10	1400 ± 10	1300 ± 10	1250 ± 10	1315 ± 10	1250 ± 10	1400 ± 10	1400 ± 10	1400 ± 10	1400 ± 10	1250 ± 10	1400 ± 10
	Actual	1289	1395	1297	1248	1316	1244	1394	1401	1395	1409	1249	1399
TFST, °F	Target	-300 ± 10	-200 ± 10	-210 ± 10	-200 ± 10	-225 ± 10	-140 ± 10	-200 ± 10	-240 ± 10	-200 ± 10	-240 ± 10	-140 ± 10	-200 ± 10
	Actual	-301	-203	-202	-202	-219	-142	-203	-243	-197	-236	-144	-206
TTC, °F	Target	-150 ± 15	-80 ± 15	---	-80 + 15	---	-80 ± 15	-200 ± 15	---	-200 ± 15	---	-100 ± 15	-200 ± 15
	Actual	-170	-115	---	-89	---	-90	-186	---	-169	---	-121	-201
TFTD, °F	Target	0^{+15}_{-10}	-20 ± 15	$+125^{+15}_{-0}$	-20 ± 15	165^{+15}_{-0}	-20 + 15	-20 ± 15	170^{+15}_{-0}	-20 ± 15	170^{+15}_{-0}	-100 ± 15	-20 ± 15
	Actual	-18	-17	+109	-22	176	-30	-38	181	-25	176	-120	-26
TSOVAL, °F	Target	-85 ± 10	-100 ± 10	-150 ± 10	-100 ± 10	-150 ± 10	--	-100 ± 10	-150 ± 10	-100 ± 10	-150 ± 10	-50 + 10	-100 ± 10
	Actual	-81	-96	-148	-113	-151	---	-132	-163	-102	-160	-55	-113
TSOVC, °F	Target	-150 ± 10	-175 ± 10	-175 ± 10	-175 ± 10	-175 ± 10	--	---	---	-175 ± 10	-225 ± 10	-150 ± 10	-175 ± 10
	Actual	-148	-127	-166	-178	-182	---	---	---	-159	-221	-142	-178
TBHR, °F	Target	-85 ± 10	-100 ± 10	-150 ± 10	-100 ± 10	-150 ± 10	---	-100 ± 10	-150 ± 10	-100 ± 10	-150 ± 10	-50 ± 10	-100 ± 10
	Actual	-99	-116	-170	-123	-175	---	-95	178	-100	-163	-57	-108
TSTDVOC, °F	Target	---	---	---		---	---	---	---	---	---	---	---
	Actual	---	---	---		---	---	---	---	---	---	---	---
Altitude, ft	Target	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
	Actual	108,000	97,700	104,500	105,000	104,500	106,400	100,500	105,000	100,200	109,600	108,000	107,000

TABLE I (Continued)

Test Number	TSOVAL, °F		TSOVC, °F	
	Target	Actual	Target	Actual
1801-05E	---	---	-150 ± 10	-146
1801-05F	---	---	-150 ± 10	-147
1801-05G	---	---	-150 ± 10	-152
1801-05H	---	---	-150 ± 10	-153
1801-05I	-150 ± 10	-146	-150 ± 10	-148
1801-05J	-150 ± 10	-148	-150 ± 10	-159
1801-05K	-150 ± 10	-151	-250 ± 10	-245
1801-05L	-150 ± 10	-151	-250 ± 10	-247
1801-05M	-150 ± 10	-153	-250 ± 10	-253
1801-05N	---	---	-150 ± 10	-147
1801-05O	---	---	-150 ± 10	-144
1801-05P	-150 ± 10	-113	-150 ± 10	-149
1801-05Q	-150 ± 10	-134	-150 ± 10	-147
1801-05R	-150 ± 10	-156	-150 ± 10	-148
1801-05S	-150 ± 10	-161	-150 ± 10	-136
1801-05T	-150 ± 10	-157	-250 ± 10	-242
1801-05U	-150 ± 10	-170	-250 ± 10	-248

TABLE I (Continued)

Firing Number		1801-06A	1801-06B	1801 06C	1801-06D	1801-07A	1801-07B	1801-07C	1801-07D	1801-08A	1801-08B	1801-08C	1801-08D	1801-10A
PFPI, psia	Target	28 ± 1	28 ± 1	46 ± 1	46 ± 1	28 ± 1	28 ± 1	28 ± 1	28 ± 1	28 ± 1	28 ± 1	46 ± 1	28 ± 1	25^{+0}_{-1}
	Actual	28.7	27.9	45.4	44.6	29.6	27.8	28.2	27.9	27.7	27.5	45.4	27.4	24.1
TFPI, °F	Target	-421.4 ± 0.4	-421.4 ± 0.4	-421.1 ± 0.4	-421.1 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 + 0.4	-421.4 + 0.4	-421.4 ± 0.4	-421.1 ± 0.4	-421.4 ± 0.4	-421.7 + 0.4
	Actual	-421.5	-421.4	-421.2	-420.8	-421.1	-420.6	-421.2	-420.4	-421.5	-420.6	-421.0	-421.2	-421.6
POPI, psia	Target	35 ± 1	48 ± 1	35 ± 1	48 ± 1	35 ± 1	48 ± 1	35 ± 1	48 ± 1	35 ± 1	48 ± 1	35 ± 1	48 ± 1	---
	Actual	34.9	47.8	35.2	48.1	35.4	47.6	35.7	47.9	36.2	48.2	34.9	47.7	---
TOPI, °F	Target	-294.0 ± 0.4	-295.3 ± 0.4	-294.0 ± 0.4	-295.3 ± 0.4	-294.0 ± 0.4	-295.3 ± 0.4	-294.0 + 0.4	-295.3 ± 0.4	-294.0 + 0.4	-295.3 ± 0.4	-294.0 ± 0.4	-295.3 ± 0.4	---
	Actual	-294.3	-295.3	-294.1	-295.0	-293.8	-295.3	-295.0	-295.9	-293.9	-295.0	-293.9	-294.5	---
PFST, psia	Target	1250 ± 10	1400 ± 10	1250 ± 10	1400 ± 10	1250 ± 10	1200 ± 10	1250 ± 10	1300 ± 10	1250 ± 10	1200 ± 10	1250 ± 10	1400 ± 10	1300 ± 10
	Actual	1236	1396	1248	1402	1248	1207	1245	1300	1248	1193	1245	1393	1299
TFST, °F	Target	-140 ± 10	-240 ± 10	-140 ± 10	-240 ± 10	-140 ± 10	300 ± 10	-140 ± 10	-300 ± 10	-140 ± 10	-140 ± 10	-140 ± 10	-140 ± 10	-300 + 10
	Actual	-141	-242	-145	-248	-142	-301	-142	-299	-141	-139	-145	-146	-300
TTC, °F	Target	-200 ± 15	---	-80 ± 15	---	-80 ± 15	---	-100 ± 15	---	---	---	-80 ± 15	---	-250^{+0}_{-20}
	Actual	-213	---	-95	---	-93	---	-100	---	---	---	-82	---	242
TFTD, °F	Target	-100 ± 15	170^{+15}_{-0}	-100 ± 15	$+170^{+15}_{-0}$	-100 ± 15	$+170^{+15}_{-0}$	-100 + 15	170 ± 15	-100 ± 15	170^{+15}_{-0}	-100 ± 15	170^{+15}_{-0}	0 ± 15
	Actual	-128	+178	-143	+111	-107	+169	-131	180	-76	171	-103	174	-8
TSOVAL, °F	Target	---	---	---	---	---	---	---	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
TSOVC, °F	Target	---	---	---	---	---	---	---	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
TBHR, °F	Target	---	---	---	---	---	---	---	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
TSTDVOC, °F	Target	---	---	---	---	---	---	---	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
Altitude, ft	Target	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
	Actual	103,100	105,400	107,000	107,400	95,900	89,400	106,100	106,300	92,500	101,200	105,400	106,900	90,000

TABLE I (Continued)

Firing Number		1801-10B	1801-10C	1801-10D	1801-10E	1801 11A	1801 12A	1801-12B	1801-13A	1801-13B	1801-14A	1801-15A	1801-15B	1801-15E
PFPI, psia	Target	25^{+0}_{-1}	23^{+0}_{-1}	23^{+0}_{-1}	---	37 + 1	37 + 1	37 ± 1	25.5^{+1}_{-0}	25.5^{+1}_{-0}	25.5^{+1}_{-0}	25.5^{+1}_{-0}	26.6^{+1}_{-0}	23.5^{+1}_{-0}
	Actual	24.6	22.5	22.5	---	36.7	37.2	37.2	27.6	26.7	25.8	25.6	26.0	24.1
TFPI, °F	Target	-421.7 ± 0.4	-421.0 ± 0.4	-421.0 ± 0.4	---	-420.0 ± 0.4	-420.0 ± 0.4	-421.1 ± 0.4	-421.4 ± 0 4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ⊥ 0.4	-421.4 ⊥ 0.4	-421.4 ± 0.4
	Actual	-422.0	-421.3	-421.4	---	-419.6	-419.8	-421.3	-421.6	-421.3	-421.5	-421.2	-421.1	-421.5
POPI, psia	Target	37 ± 1	37 ± 1	37 ± 1	---	46 + 1	46 + 1	41 + 1	33^{+1}_{-0}	43 ± 1	33^{+1}_{-0}	33^{+1}_{-0}	45 ⊥ 1	28 ± 1
	Actual	38.4	36.9	36.3	---	46.2	46.9	40.8	33.7	43.5	33.3	33.6	45.4	28.7
TOPI, °F	Target	---	---	---	---	-293.5 ± 0.4	-293.5 ± 0.4	-293.5 ± 0.4	294.5 ± 0.4	-294.5 ± 0.4	-294.5 + 0.4	-294.5 + 0.4	-294.5 + 0.4	-295.0 ± 0.4
	Actual	---	---	---	--	-294.3	-293.7	-294.5	-294.9	-294.9	-294.8	-294.8	-294.7	-295.1
PFST, psia	Target	1300 ± 10	1300 ± 10	1300 ± 10	1450 ± 10	1300 ⊥ 10	1300 ± 10	1380 ± 10	1250 ± 10	1400 ± 10	1250 ± 10	1250 ± 10	1400 ± 10	1400 ± 10
	Actual	1308	1309	1307	1452	1290	1299	1381	1245	1401	1253	1245	1398	1405
TFST, °F	Target	-300 ± 10	-300 ± 10	-300 ± 10	-250 ± 10	-175 ± 10	-175 ± 10	-225 ± 10	140 ± 10	-240 ± 10	-140 ± 10	-140 ± 10	-240 ± 10	-240 ± 10
	Actual	-304	-308	-304	-256	-178	-166	-220	-132	-244	-135	-137	-228	-240
TTC, °F	Target	-150^{+20}_{-0}	-250^{+0}_{-20}	-150^{+20}_{-0}	---	---	-	---	-250 ± 25	-150^{+20}_{-10}	-250 ± 25	-250 ± 25	-250 ± 25	-250 ± 25
	Actual	144	-258	-150	---	---	---	---	-243	-142	-249	-235	-237	-239
TFTD, °F	Target	0 ± 15	0 ± 15	0 ± 15	---	---	---	125^{+15}_{-0}	-50 ± 15	50 ± 25	-50 ± 15	-50 + 15	50 + 15	50 + 15
	Actual	-12	-3	-2	---	---	---	139	-62	36	-46	-58	54	54
TSOVAL, °F	Target	---	---	---	---	---	---	---	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
TSOVC, °F	Target	---	---	---	---	--	---	---	-60^{+0}_{-20}	-160^{+0}_{-60}	-60^{+20}_{-0}	-40^{+0}_{-20}	-150^{+0}_{-60}	---
	Actual	---	---	---	---	---	---	---	-80	-175	-79	-60	-184	---
TBHR, °F	Target	---	---	---	---	---	---	---	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	--	---	---	---	---	---	---
TSTDVOC, °F	Target	---	---	---	---	---		---	---	---	---	--	---	---
	Actual	--	---	---	-	- -	---	---	---	---	---	---	---	---
Altitude, ft	Target	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
	Actual	108,200	107,400	107,200	71,900	101,300	98,300	103,800	98,300	105,900	106,100	99,800	102,900	106,400

TABLE I (Continued)

Firing Number		1801-16A	1801-16B	1801-16C	1801-16D	1801-16E	1801-17A	1801-18A	1801-18B	1801-18C	1801-18D	1801-18E	1801-19A	1801-19B
PFPI, psia	Target	25.5^{+1}_{-0}	25.5^{+1}_{-0}	25.5^{+1}_{-0}	41^{+1}_{-0}	23.5^{+1}_{-0}	25.5^{+1}_{-0}	25.5^{+1}_{-0}	25.5^{+1}_{-0}	25.5^{+1}_{-0}	38 + 1	23.5^{+1}_{-0}	25.5^{+1}_{-0}	25.5^{+1}_{-0}
	Actual	26.3	25.7	25.8	42.3	24.4	25.7	25.9	26.5	25.5	38.2	23.6	27.3	25.7
TFPI, °F	Target	421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-422.0 + 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 + 0.4	-421.4 + 0.4	-421.4 + 0.4	-421.4 ± 0.4
	Actual	-421.3	-421.0	-421.7	-422.1	421.6	-421.7	-420.9	-421.2	-421.6	-421.6	421.4	421.3	-421.5
POPI, psia	Target	33^{+1}_{-0}	45 ± 1	45 ± 1	35 ± 1	28 ± 1	33^{+1}_{-0}	33^{+1}_{-0}	45 ± 1	46 ± 1	45 ± 1	28 ± 1	33^{+1}_{-0}	45 ± 1
	Actual	34.8	46.4	45.1	34.8	28.3	33.1	33.5	45.7	46.0	44.5	28.4	33.3	44.1
TOPI, °F	Target	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 + 0.4	-295.0 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 + 0.4	-295.0 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4
	Actual	-294.7	-294.6	-294.6	-294.6	-295.2	-295.1	-294.7	-294.6	-294.6	-294.6	-295.1	-294.5	-294.6
PFST, psia	Target	1200 ± 10	1300 ± 10	1300 ± 10	1200 ± 10	1400 ± 10	1250 ± 10	1250 ± 10	1400 ± 10	1400 ± 10	1400 ± 10	1400 ± 10	1200 ± 10	1300 ± 10
	Actual	1204	1304	1311	1205	1402	1244	1246	1405	1405	1390	1403	1182	1306
TFST, °F	Target	-200 ± 10	-300 ± 10	-300 ± 10	-200 ± 10	-240 ± 10	140 ± 10	-140 ± 10	-240 ± 10	-240 + 10	-140 + 10	-240 ± 10	-200 ± 10	-300 ± 10
	Actual	-197	-303	-306	-206	-245	-141	-148	-243	-242	-145	-243	194	-298
TTC, °F	Target	-250 ± 25	-150^{+20}_{-10}	-250 + 25	-150^{+20}_{-10}	-250^{+20}_{-10}	-250 ± 25	-250 ± 25	-150^{+20}_{-10}	-250 + 25	-250 ± 25	-150^{+20}_{-10}	-250 ± 25	-150^{+25}_{-0}
	Actual	-251	-156	-243	-163	-258	-252	-260	-153	-250	-249	-153	-243	144
TFTD, °F	Target	-50 ± 15	50 ± 15	50 + 15	-50 ± 15	50 ± 15	-100^{+25}_{-0}	-100^{+25}_{-0}	50 ± 25	50 ± 25	50 ± 25	50 ± 25	-100^{+25}_{-0}	50 ± 25
	Actual	-43	+48	49	-59	42	-98	-76	63	56	55	63	-81	61
TSOVAL, °F	Target	---	---	---	---	---	---	---	---	---	-	---	---	---
	Actual	---	---	---	---	--	---	---	---	---	---	---	---	---
TSOVC, °F	Target	-40^{+0}_{-20}	-150^{+0}_{-60}	-150^{+0}_{-60}	-150^{+0}_{-60}	---	-40^{+0}_{-20}	-40^{+0}_{-20}	-150^{+0}_{-60}	-150^{+0}_{-60}	-150^{+0}_{-60}	---	-40^{+0}_{-20}	-150^{+0}_{-60}
	Actual	-74	-164	-171	-150	---	-66	-78	-166	-175	-180	---	-81	-186
TBHR, °F	Target	---	---	---	---	---	---	---	---	---	---	---	--	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
TSTDVOC, °F	Target	+50 ± 25	+ 50 ± 25	+50 ± 25	+50 ± 25	+50 ± 25	+50 + 25	+50 ± 25	+50 ± 25	+50 ± 25	+50 ± 25	+50 + 25	+50 ± 25	+50 ± 25
	Actual	+24	+30	+31	+26	+23	+22	+43	+43	+38	+35	+32	+43	+39
Altitude, ft	Target	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
	Actual	93,800	106,400	105,900	109,800	109,600	93,300	90,900	106,300	106,400	106,100	104,700	90,300	106,100

TABLE I (Continued)

Firing Number		1801 19C	1801-19D	1801-19E	1801-20A	1801-20B	1801-20C	1801 20D	1801-20E	1801-21A	1801-21B	1801-21C	1801-21D	1801-22A
PFPI, psia	Target	25.5^{+1}_{-0}	25.5^{+1}_{-0}	21.5^{+1}_{-0}	25.5^{+1}_{-0}	25.5^{+1}_{-0}	38^{-1}_{-0}	29 ± 1	21.5^{+1}_{-0}	41 ± 1	27^{+1}_{-0}	26.5^{+1}_{-0}	28.5^{+1}_{-0}	25.5^{+1}_{-0}
	Actual	25.9	25.7	21.7	26.2	25.8	38.2	20.3	21.7	40.1	27.0	26.9	28.5	25.6
TFPI, °F	Target	-421.4 ± 0.4	421.4 ± 0.4	421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-420.9 ± 0.4	-421.4 ± 0.4	-420.1 + 0.4	-421.4 ± 0.4
	Actual	-421.3	421.2	420.9	-421.1	-421.2	-421.6	-421.4	-421.3	-421.6	-420.5	-420.7	-420.1	-421.1
POPI, psia	Target	45 ± 1	45 ± 1	28 ± 1	33^{+1}_{-0}	33^{+1}_{-0}	33^{+1}_{-0}	37 ± 1	28 ± 1	45 ± 1	45 ± 1	45 ± 1	45 ± 1	45 ± 1
	Actual	44.4	44.1	28.4	33.6	33.6	33.6	36.9	28.2	45.2	45.3	44.9	45.2	45.3
TOPI, °F	Target	-294.5 ± 0.4	-294.5 ± 0.4	-295.0 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 + 0.4	-294.5 ± 0.4	-295.0 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4
	Actual	-294.5	-294.6	-295.0	-294.5	-294.6	-294.6	-294.6	-295.0	-294.6	-294.5	-294.6	-294.6	295.0
PFST, psia	Target	1370 ± 10	1200 ± 10	1400 ± 10	1250 ± 10	1200 + 10	1200 ± 10	1250 ± 10	1400 ± 10	1300 ± 10	1300 ± 10	1400 ± 10	1400 ± 10	1380 ± 10
	Actual	1378	1208	1400	1248	1198	1204	1249	1401	1301	1308	1405	1400	1386
TFST, °F	Target	270 ± 10	300 ± 10	-240 ± 10	-140 ± 10	-200 ± 10	-200 ± 10	-250 ± 10	-240 ± 10	-300 ± 10	-300 ± 10	-240 + 10	-240 ± 10	-270 ± 10
	Actual	-274	-299	-242	-145	-205	-204	-249	-242	-294	-306	-243	-242	-272
TTC, °F	Target	-150^{+25}_{-0}	250 ± 25	250 ± 25	-250 ± 25	-250 ± 25	-150^{+20}_{10}	-200 ± 25	-250 ± 25	-150^{+20}_{-10}	-150^{+20}_{-10}	-150^{+20}_{-10}	-275^{+0}_{-25}	-250 ± 25
	Actual	134	-252	-250	-223	-257	155	-200	-234	-128	-142	-132	-275	-266
TFTD, °F	Target	50 ± 25	50 ± 25	50 ± 25	-100^{+25}_{-0}	-100^{-25}_{-0}	-100^{+25}_{-0}	0 ± 25	50 ± 25	50 ± 25	50 ± 25	50 + 25	50 ± 25	50 ± 25
	Actual	59	63	33	-91	94	89	-1	47	76	61	64	66	39
TSOVAL, °F	Target	---	---	---	---	--		-	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
TSOVC, °F	Target	-150^{+0}_{-60}	-150^{+0}_{-60}	---	-40^{+0}_{-20}	-40^{+0}_{-20}	-40^{+0}_{-20}	-100 ± 50	---	-100 ± 25	-100 ± 25	-100 ± 25	-100 ± 25	-100 ± 25
	Actual	-187	-186	---	-64	-66	-70	-147	---	-89	-126	-115	-110	-122
TBHR, °F	Target	-	---	---	---	--	---	- -	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	--	---	---
TSTDVOC, °F	Target	50 ± 25	50 ± 25	50 ± 25	50 + 25	50 ± 25	50 ± 25	50 ± 25	50 ± 25	50 ± 25	50 ± 25	50 ± 25	50 ± 25	50 ± 25
	Actual	40	43	37	44	35	38	38	36	51	37	41	38	28
Altitude, ft	Target	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
	Actual	105,600	109,600	109,600	104,500	110,200	110,700	110,100	112,200	95,100	111,700	107,000	108,400	101,700

TABLE I (Continued)

Firing Number		1801-22B	1801-22C	1801-22D	1801-22E	1801-23A	1801-23B	1801-23C	1801-23D	1801-23E	1801-24A	1801-24B	1801-25A	1801-25B
PFPI, psia	Target	41 ± 1	25.5^{+1}_{-0}	25.5^{+1}_{-0}	21.5^{+1}_{-0}	25.5^{+1}_{-0}	25.5^{+1}_{-0}	25.5^{+1}_{-0}	41 ± 1	23.5^{+1}_{-0}	26^{+1}_{-0}	26^{+1}_{-0}	26^{+1}_{-0}	26^{+1}_{-0}
	Actual	41.0	26.8	26.2	22.3	26.3	25.9	26.4	41.1	24.7	27.1	26.1	26.8	26.3
TFPI, °F	Target	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 + 0.4	-421.4 + 0.4	-421.4 ± 0.4	-421.4 ± 0.4
	Actual	-421.5	-420.7	-421.4	-421.2	-421.8	-422.0	-421.7	-421.3	-421.4	421.7	-421.6	-421.8	-421.5
POPI, psia	Target	45 ± 1	45 ± 1	45 ± 1	28 ± 1	33^{+1}_{-0}	33^{+1}_{-0}	33^{+1}_{-0}	33^{+1}_{-0}	28^{+1}_{-0}	45 ± 1	45 ± 1	33^{+1}_{-0}	45 ± 1
	Actual	45.1	44.8	44.4	28.1	33.9	34.6	33.7	33.4	28.2	45.3	44.8	34.0	44.7
TOPI, °F	Target	294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-295.0 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-294.5 ± 0.4	-295.0 ± 0.4
	Actual	-294.2	-294.9	-294.5	294.7	-294.6	-294.6	-294.8	-294.1	-295.1	295.4	-294.9	-294.5	-295.3
PFST, psia	Target	1380 ± 10	1300 ± 10	1200 ± 10	1400 ± 10	1200 + 10	1250 ± 10	1250 ± 10	1400 ± 10	1400 ± 10	1400 ± 10	1300 + 10	1400 ± 10	1300 ± 10
	Actual	1380	1304	1203	1409	1197	1243	1249	1304	1397	1397	1304	1385	1303
TFST, °F	Target	-270 ± 10	-300 ± 10	-300 ± 10	-240 + 10	-200 + 10	140 ± 10	-140 ± 10	-240 ± 10	-200 ± 10	-200 + 10	215 ± 10	200 ± 10	-215 ± 10
	Actual	-270	-298	-299	-241	-201	-141	-139	-241	-202	-202	-204	204	-216
TTC, °F	Target	-250 ± 25	-250 ± 25	-150^{+20}_{-10}	-250 + 25	-150^{+20}_{-10}	275 ± 25	-150^{+20}_{-10}	-275 + 25	-80^{+20}_{10}	-80^{+20}_{-10}	---	-250 ± 50	---
	Actual	-259	-257	-151	-268	-157	292	-151	-267	-81	-81	-	-266	---
TFTD, °F	Target	50 ± 25	50 ± 25	50 ± 25	50 + 25	100^{+25}_{-0}	100^{+25}_{-0}	-100^{+25}_{-0}	-100^{+25}_{0}	50 + 25	50 ± 25	170^{+15}_{-0}	-100 ± 20	170^{+15}_{-0}
	Actual	37	49	39	36	81	-93	-86	-88	44	50	95	-113	179
TSOVAL, °F	Target	---	---	---	---	---	--	---	---	---	---	---	---	---
	Actual	---	---	---	---	-	---	---	---	---	-	---	---	---
TSOVC, °F	Target	-100 ± 50	-100 ± 50	-100 ± 50	---	-150 + 50	150 ± 50	-150 ± 50	-150 ± 50	---	-150 ± 50	-150 ± 50	-150 + 50	150 ± 50
	Actual	-134	-104	-139	---	-137	-110	-141	-141	---	108	-102	-143	-125
TBHR, °F	Target	---	---	---	---	---	---	---	---	---	---	-	---	---
	Actual	---	---	---	---	-	---	---	--	---	---	---	---	---
TSTDVOC, °F	Target	50 ± 25	50 ± 25	50 ± 25	50 ± 25	50 ± 25	-50 ± 25	50 ± 25	50 ± 25	50 ± 25	50 + 25	50 ± 25	50 ± 25	50 ± 25
	Actual	21	25	17	17	27	31	28	26	34	32	30	-13	-14
Altitude, ft	Target	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
	Actual	109,400	109,400	112,500	112,500	105,700	112,300	112,800	111,400	110,700	102,200	108,000	102,600	102,700

TABLE I (Continued)

Firing Number		1801-25C	1801-25D	1801-25E	1801-26A	1801-26AA	1801-26B	1801-27A	1801-28A	1801-28B	1801-28C	1801-29A	1801-29B	1801-29C
PFPI, psia	Target	26^{+1}_{-0}	26^{+1}_{-0}	23.5^{+1}_{-0}	26^{+1}_{-0}	26^{+1}_{-0}	26^{+1}_{-0}	26^{+1}_{-0}	40 ± 1	40 ± 1	40 ± 1	40 ± 1	26 ± 0.5	26 ± 0.5
	Actual	28.2	26.2	24.4	27.4	26.1	26.4	26.8	39.4	39.4	39.3	39.0	26.1	25.6
TFPI, °F	Target	-421.4 ± 0.4	-421.4 ± 0.4	421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-422.0 ± 0.4	-422.0 ± 0.4	422.0 ± 0.4	-422.0 ± 0.4	-420.4 ± 0.4	-420.4 ± 0.4
	Actual	421 8	-421.0	-421.3	-422.0	-421.5	-421.7	-421.6	-421.6	-421.6	-421.2	-422.0	-420.7	-420.5
POPI, psia	Target	45 ± 1	45 ± 1	28 ± 1	33^{+1}_{-0}	33^{+1}_{-0}	45 ± 1	33^{+1}_{-0}	30 ± 1	30 ± 1	38 ± 1	38 ± 1	45 ± 1	45 ± 1
	Actual	45.7	44.2	27.7	35.2	34.2	46.1	33.6	29.3	29.7	39.0	38.0	45.3	44.7
TOPI, °F	Target	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	---	---	294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4
	Actual	-295.3	-294.7	-294.4	-294.5	294.8	-295.2	-294.5	---	---	-293.5	-294.1	-293.9	-294.3
PFST, psia	Target	1400 ± 10	1300 ± 10	1400 ± 10	1250 ± 10	1250 ± 10	1180 ± 10	1250 ± 10	---	---	1400 ± 10	1400 ± 10	1400 ± 10	1400 ± 10
	Actual	1386	1300	1403	1250	1243	1178	1248	---	---	1391	1412	1420	1420
TFST, °F	Target	-200 ± 10	-265 ± 10	-240 ± 10	-140 ± 10	140 ± 10	-210 ± 10	-140 ± 10	---	---	-240 ± 10	-240 ± 10	-240 ± 10	-240 ± 10
	Actual	202	-267	-240	-146	-141	-213	-137	---	---	-247	-245	-238	-241
TTC, °F	Target	-250 ± 50	---	-275 ± 25	-200 ± 25	-200 ± 25	---	-250 ± 25	250 ± 25	-250 ± 25	-250 ± 25	250 ± 25	-275 ± 25	-150 ± 25
	Actual	-236	- -	262	-206	-203	---	-264	-266	-264	-259	-255	-284	-161
TFTD, °F	Target	50 ± 50	170^{+15}_{-0}	50 ± 50	100 ± 20	100 ± 20	170^{+15}_{-0}	-100 ± 20	---	---	---	50 ± 50	50 ± 50	50 ± 50
	Actual	34	170	29	-152	-92	169	-45	---	---	---	39	39	35
TSOVAL, °F	Target	---	---	---	---	---	---	---	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
TSOVC, °F	Target	-150 ± 50	-150 ± 50	---	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	---	---	---	-100 ± 50	-150 ± 50	-150 ± 50
	Actual	-175	-173	--	-120	-152	-163	-152	---	---	---	-164	-156	-158
TBHR, °F	Target	---	---	---	---	---	---	---	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
TSTDVOC, °F	Target	50 ± 25	50 ± 2[illegible]	50 ± 25	---	---	---	---	---	---	---	50 ± 50	50 ± 50	50 ± 50
	Actual	-64	70	+11	---	---	---	---	---	---	---	19	28	-28
Altitude, ft	Target	100,000	100,000	100,000	100,000	100,000	100,000	100,000	---	---	---	---	---	---
	Actual	106,400	109,200	107,200	96,800	90,600	105,900	85,400	---	---	---	---	---	---

TABLE I (Continued)

Firing Number		1801-29D	1801-29E	1801-30A	1801-31A	1801-31B	1801-31C	1801-31D	1801-31E	1801-32A	1801-32B	1801-32C	1801-32D	1801-32E
PFPI, psia	Target	26 ± 0.5	26 ± 0.5	26.5 ± 0.5	26.5 ± 0.5	26.5 ± 0.5	26.5 ± 0.5	26.5 ± 0.5	26.5 ± 0.4	26.5 ± 0.5	26.5 ± 0.5	26.5 ± 0.5	26.5 ± 0.5	26.5 ± 0.5
	Actual	25.7	25.8	26.4	26.6	26.6	26.7	26.8	26.6	25.9	26.2	26.2	26.0	26.0
TFPI, °F	Target	-420.0 ± 0.4	420.0 ± 0.4	-420.4 ± 0.4	-420.4 ± 0.4	-420.4 ± 0.4	420.4 ± 0.4	420.4 ± 0.4	-420.4 ± 0.4	-420.4 ± 0.4	-420.4 ± 0.4	-420.4 ± 0.4	-420.4 ± 0.4	-420.4 ± 0.4
	Actual	-420.2	-420.5	-420.3	-420.4	-420.5	-420.0	-419.9	-419.8	-420.1	-420.4	-420.2	-420.5	-420.4
POPI, psia	Target	45 ± 1	45 ± 1	33^{+1}_{-0}	45 ± 1	33^{+1}_{-0}	45 ± 1	45 ± 1	45 ± 1	45 ± 1	45 ± 1	45 ± 1	45 ± 1	45 ± 1
	Actual	44.2	44.1	34.0	46.2	32.8	44.8	45.0	45.0	45.9	44.9	44.9	45.1	44.4
TOPI, °F	Target	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4
	Actual	-294.1	294.3	294.7	-294.0	-294.3	-294.3	294.4	-294.3	-294.8	-294.8	-294.8	-294.3	-295.2
PFST, psia	Target	1300 ± 10	1300 ± 10	1250 ± 10	1300 ± 10	1200 ± 10	1400 ± 10	1400 ± 10	1400 ± 10	1200 ± 10	1300 ± 10	1400 ± 10	1200 ± 10	1200 ± 10
	Actual	1323	1324	1257	1307	1204	1405	1403	1399	1209	1307	1400	1199	1202
TFST, °F	Target	-300 ± 10	-300 ± 10	-140 ± 10	-300 ± 10	-200 ± 10	-240 ± 10	-240 ± 10	-240 ± 10	300 ± 10	-300 ± 10	-240 ± 10	-200 ± 10	-200 ± 10
	Actual	-298	-300	-139	-298	-198	-240	-240	-238	-300	-298	-246	-202	-196
TTC, °F	Target	-275 ± 25	-150 ± 25	-275 ± 25	-275 ± 25	-275 ± 25	---	0 ± 25	-50 ± 25	-275 ± 25	-275 ± 25	-75 ± 15	-75 ± 15	-85^{+0}_{-15}
	Actual	-283	-174	-291	-284	-281	---	-11	-57	-280	-275	-76	-64	-94
TFTD, °F	Target	50 ± 50	50 ± 50	-100 ± 20	50 ± 50	-100 ± 50	50 ± 50	50 ± 50	50 ± 50	50 ± 50	50 ± 50	50 ± 50	50 ± 50	50 ± 50
	Actual	29	38	-103	63	-100	48	14	32	58	40	49	43	55
TSOVAL, °F	Target	---	---	---	---	---	---	---	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
TSOVC, °F	Target	-150 ± 50	-150 ± 50	-100 ± 50	-150 ± 50	-100 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50
	Actual	-166	-153	-144	-154	-101	-119	-98	-128	-120	-119	-110	-115	-117
TBHR, °F	Target	---	---	---	---	---	---	---	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
TSTDVOC, °F	Target	50 ± 50	50 ± 50	50 ± 50	50 ± 25	50 ± 25	50 ± 25	50 ± 25	50 ± 25	50 ± 25	50 ± 25	50 ± 25	50 ± 25	50 ± 25
	Actual	21	29	28	48	45	51	47	37	39	34	39	30	36
Altitude, ft	Target	---	---	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
	Actual	---	---	100,800	91,400	101,700	104,800	103,200	94,300	91,400	99,000	99,000	100,300	100,300

TABLE I (Continued)

Firing Number		1801-32F	1801-32G	1801-33A	1801-33B	1801-33C	1801-33D	1801-33E	1801-34A	1801 34B	1801-34C	1801 34D	1801-34E	1801-35A
PFPI, psia	Target	26.5 ± 0.5	26.5 ± 0.5	26.5 ± 0.5	26.5 ± 0.5	26.5 ± 0.5	26.5 ± 0.5	26.5 ± 0.5	26.5^{+1}_{-0}	26.5^{+1}_{-0}	26.5^{+1}_{-0}	26.5^{+1}_{0}	26.5^{+1}_{-0}	26.5^{+1}_{-0}
	Actual	25.9	25.7	25.8	26.0	25.9	26.2	26.0	27.7	27.6	28.1	28.1	26.8	28.6
TFPI, °F	Target	-420.4 ± 0.4	-420.4 ± 0.4	-420.4 ± 0.4	-420.4 ± 0.4	420.4 ± 0.4	-420.4 ± 0.4	420.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4
	Actual	-420.0	-420.2	-420.1	-420.5	-420.5	420.4	-420.3	-421.7	-421.0	-421.7	-421.2	-421.4	-421.4
POPI, psia	Target	45 ± 1	45 ± 1	45 ± 1	45 ± 1	45 ± 1	45 ± 1	45 ± 1	45 ± 1	45 ± 1	45 ± 1	45 ± 1	45 ± 1	45 ± 1
	Actual	45.0	45.4	45.7	45.3	44.3	44.7	46.5	45.7	45.0	46.2	46.0	45.1	45.4
TOPI, °F	Target	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4
	Actual	-294.5	-294.4	-291.0	-294.7	-294.8	-294.8	-294.7	-295.1	-295.1	-294.6	-294.6	-294.3	-295.4
PFST, psia	Target	1200 ± 10	1300 ± 10	1200 ± 10	1300 ± 10	1400 ± 10	1250 ± 10	1200 ± 10	1400 ± 10	1300 ± 10	1400 ± 10	1250 ± 10	1300 ± 10	1400 ± 10
	Actual	1205	1300	1206	1303	1395	1247	1205	1398	1294	1387	1247	1301	1381
TFST, °F	Target	-300 ± 10	-300 ± 10	-200 ± 10	-300 ± 10	-240 ± 10	-140 ± 10	-300 ± 10	-200 ± 10	-215 ± 10	-200 ± 10	-140 ± 10	-265 ± 10	-140 ± 10
	Actual	-301	-293	-199	-302	-242	-140	-301	-201	-216	-201	-140	-268	-136
TFIC, °F	Target	85^{+0}_{-15}	-85^{+0}_{-15}	-100 ± 15	100 ± 15	-100 ± 15	-100 ± 15	-100 ± 15	-80^{+20}_{-10}	---	250 ± 25	-80^{+20}_{-10}	---	-250 ± 25
	Actual	-90	-90	-84	-85	-89	-89	-86	-85	---	-239	-92	---	-260
TFID, °F	Target	50 ± 50	50 ± 50	50 ± 50	50 ± 50	50 ± 50	50 ± 50	50 ± 50	50^{+0}_{-50}	170^{+15}_{-0}	50^{+0}_{-50}	50^{+0}_{-50}	170^{+15}_{-0}	50^{+0}_{-50}
	Actual	54	51	67	64	65	79	68	69	179	71	58	174	31
TSOVAL, °F	Target	---	---	---	---	---	---	---	---	--	---	-	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
TSOVC, °F	Target	-150 ± 50	-150 ± 50	-100 ± 50	-100 ± 50	-100 ± 50	-100 ± 50	-100 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50
	Actual	119	-118	-55	-139	-140	146	-141	-111	143	-100	-132	-151	-115
TBHR, °F	Target	---	---	---	---	---	---	---	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
TSTDVOC, °F	Target	50 ± 25	-50 ± 25	-50 ± 25	-50 ± 25	-50 ± 25	-50 ± 25	-50 ± 25	---	---	---	---	---	---
	Actual	35	32	59	46	48	59	49	---	---	---	---	---	---
Altitude, ft	Target	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
	Actual	106,700	108,600	99,000	113,100	110,700	115,800	113,100	100,300	110,700	105,700	102,200	114,500	95,500

TABLE I (Continued)

Firing Number		1801-35B	1801-36A	1801-36B	1801-36C	1801-36D	1801-36E	1801-37A	1801-37B	1801-37C	1801-37D	1801-37E	1801-38A	1801-38B
PFPI, psia	Target	26.5^{+1}_{-0}	26.5^{+1}_{-0}	$26\ 5^{+1}_{-0}$	41 ± 1	26.6^{+1}_{-0}	26.5^{+1}_{-0}	26.5^{+1}_{-0}	26.5^{+1}_{-0}	26.5^{+1}_{-0}	41 ± 1	26.5^{+1}_{-0}	37 + 1	37 + 1
	Actual	27.4	26.8	26.9	41.4	26.6	27.9	26.7	26.6	27.0	41.0	28.6	38.0	36.7
TFPI, °F	Target	-421.4 ± 0.4	-421 4 + 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-420.5 ± 0.4
	Actual	-421.3	-421.4	-420.4	-421.4	-420.6	420 9	-421.4	420.9	-421.2	-420.6	-421.4	-421.4	-420.6
POPI, psia	Target	45 ± 1	33^{+1}_{-0}	45 + 1	45 + 1	45 ± 1	45 ± 1	33^{+1}_{-0}	45 ± 1	33^{+1}_{-0}	45 ± 1	45 ± 1	40 ± 1	41 ± 1
	Actual	45.6	33.6	45.9	45.2	45.0	44.4	33.3	45.8	33.5	45.0	45.5	41.3	41.4
TOPI, °F	Target	-295 0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295 0 + 0.4	-295.0 ± 0.4	295.0 ± 0.4	-294.5 ± 0.4
	Actual	-295.4	-294.6	-294.4	-294.8	-294.8	-294.3	-294.9	-294.9	-294.8	-294 7	-294.8	-295.0	-294.9
PFST, psia	Target	1180 ± 10	1250 ± 10	1200 ± 10	1400 ± 10	1300 ± 10	1400 ± 10	1250 ± 10	1200 ± 10	1250 ± 10	1300 + 10	1400 ± 10	1250 ± 10	1300 ± 10
	Actual	1174	1250	1205	1388	1298	1388	1246	1195	1237	1296	1380	1254	1302
TFST, °F	Target	-210 ± 10	-140 ± 10	-260 ± 10	-200 ± 10	-265 ± 10	-200 ± 10	-140 + 10	-260 + 10	-140 ± 10	-265 ± 10	-200 ± 10	-175 + 10	-200 ± 10
	Actual	-209	-139	-260	-202	-266	-199	-140	-261	-146	-276	-207	-177	-206
TTC, °F	Target	---	-200 ± 25	---	-250 + 25	-200 + 25	0 ± 15	-250 ± 25	-200 ± 25	-200 ± 25	-200 + 25	+25 ± 15	-170 ± 15	-100 ± 15
	Actual	---	-192	--	-236	-198	-8	-248	-208	-205	209	+18	-157	-114
TFTD, °F	Target	170^{+15}_{-0}	-100 + 20	170^{+15}_{-0}	50^{+0}_{-50}	170^{+15}_{-0}	50^{+0}_{-50}	-100 ± 20	170^{+15}_{-0}	-100 ± 20	170^{+15}_{-0}	50^{+0}_{-50}	-70 ± 15	125^{+15}_{-0}
	Actual	183	-92	168	73	174	24	-91	173	-99	171	23	-53	125
TSOVAL, °F	Target	---	---	---	--		---	---	---	---	---	---	---	---
	Actual	---	-		---	---	---	---	---	---	---	---	---	---
TSOVC, °F	Target	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	---	-150 ± 50	-150 + 50	-150 ± 50	-150 ± 50	---	-150 ± 50	-150 ± 50
	Actual	-145	-119	-135	-160	157	---	-147	-155	-160	-141	---	-108	-116
TBHR, °F	Target	---	--	---	---	---	---	---	---	---	---	---	---	---
	Actual	---	---	- -	---		---	---	---	---	---	---	---	
TSTDVOC, °F	Target	---	---	---	---	---	---	---	---	---	---	---	---	
	Actual	---	---	---	---	---	--	---	---	---	--	---	---	---
Altitude, ft	Target	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
	Actual	105,700	83,300	112,200	106,700	113,100	64,300	93,300	101,800	106,700	106,700	112,300	98,400	103,700

TABLE I (Continued)

Firing Number		1801-38C	1801-38D	1801-38E	1801-39A	1801-39B	1801-39C	1801-39D	1801-39E	1801-40A	1801-40 AA	1801-40B	1801-40C	1801-40D
PFPI, psia	Target	41 ± 1	41 ± 1	26.5^{+1}_{-0}	41^{+1}_{-0}	41^{+1}_{-0}	27^{+1}_{-0}	41^{+1}_{-0}	41^{+1}_{-0}	27^{+0}_{-1}	41^{+1}_{-0}	27^{+0}_{-1}	27^{+0}_{-1}	41^{+1}_{-0}
	Actual	41.2	41.0	27.9	41.8	41.8	27.2	42.2	40.6	26.7	41.6	26.5	27.5	41.2
TFPI, °F	Target	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4
	Actual	-421.6	-421.1	-420.9	-421.2	-420.9	-421.5	-421.6	-421.4	-421.5	-421.2	-421.4	-421.7	-420.6
POPI, psia	Target	45 ± 1	45 ± 1	45 ± 1	33^{+1}_{-0}	33^{+1}_{-0}	33^{+1}_{-0}	33^{+1}_{-0}	45^{+1}_{-0}	45^{+1}_{-0}	45^{+1}_{-0}	45^{+1}_{-0}	45^{+1}_{-0}	45^{+1}_{-0}
	Actual	45.7	45.1	45.3	33.9	34.0	33.3	33.8	46.0	46.1	46.0	45.6	45.3	45.6
TOPI, °F	Target	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4
	Actual	-294.8	-294.3	-294.4	-295.4	-295.1	-295.3	-295.0	-294.7	-295.1	-295.1	-295.2	-294.4	-294.1
PFST, psia	Target	1400 ± 10	1300 ± 10	1400 ± 10	1250 ± 10	1300 ± 10	1250 ± 10	1250 ± 10	1300 ± 10	1400 ± 10	1400 ± 10	1300 ± 10	1300 ± 10	1300 ± 10
	Actual	1390	1295	1394	1243	1301	1249	1246	1297	1404	1406	1302	1305	1301
TFST, °F	Target	-200 ± 10	-265 ± 10	-200 ± 10	-140 ± 10	-260 ± 10	-140 ± 10	-140 ± 10	-200 ± 10	-200 ± 10	-200 ± 10	-265 ± 10	-265 ± 10	-265 ± 10
	Actual	-201	-269	-203	-143	-263	-144	-145	-203	-199	200	-267	-263	-264
TTC, °F	Target	-80^{+20}_{-10}	---	+50 ± 15	-80^{+20}_{-10}	---	---	-275 ± 25	---	-80^{+20}_{-10}	80^{+20}_{-10}	---	-200 ± 25	---
	Actual	-78	---	+48	-86	---	---	-279	---	-89	-86	---	-194	---
TFID, °F	Target	50^{-0}_{-50}	170^{+15}_{-0}	50^{+0}_{-50}	0 ± 15	170^{+15}_{-0}	-100 ± 15	-100 ± 15	---	0 ± 25	0 ± 25	170^{+15}_{-0}	50 ± 25	170^{+15}_{-0}
	Actual	19	173	23	5	169	-89	-99	--	-13	24	172	67	177
TSOVAL, °F	Target	---	-	---	---	--	---	-	---	---	---	---	---	---
	Actual	---	-	---	---	--	---	---	---	---	---	---	---	---
TSOVC, °F	Target	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	---	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50
	Actual	-161	-144	-155	-160	-153	-165	-170	---	-152	-171	-172	-133	-156
TBHR, °F	Target	---	---	--	---	---	---	---	---	---	---	---	---	---
	Actual	---	--	---	---	---	---	---	---	---	---	--	---	---
TSTDVOC, °F	Target	--	---	--	---	---	---	--	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
Altitude, ft	Target	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
	Actual	103,800	75,400	109,600	99,400	99,800	100,300	102,400	109,000	88,200	92,000	103,200	98,700	104,500

TABLE I (Continued)

Firing Number		1801-41A	1801 41B	1801-41C	1801-41D	1801-42A	1801-42B	1801 42C	1801-42D	1801-42E	1801-43A	1801-43B	1901-01A	1901-01B
PFPI, psia	Target	41^{+1}_{-0}	41^{+1}_{0}	41^{+1}_{-0}	27^{+0}_{1}	35^{+1}_{-0}	26.5^{+1}_{-0}	26.5^{+1}_{-0}	26.5^{+1}_{-0}	41 + 1	26.5 ± 0.5	26.5 ± 0.5	26.5 ± 0 5	26.5 ± 0.5
	Actual	41.3	41.3	41.5	26.8	35.8	27.2	27 0	27.1	42.1	26.6	26.0	26 5	26.5
TFPI, °F	Target	-421.4 ± 0 4	-421.4 ± 0.4	-421.4 + 0.4	-421.4 ± 0 4	-420.4 + 0.4	-420.4 ± 0.4	-420.4 ± 0.4	-420 4 + 0.4	-420 4 ± 0.4	-420.4 ± 0.4	-420.4 ± 0.4	-420.4 ± 0.4	-420.4 + 0.4
	Actual	-421.3	-421.2	-421.4	-421.7	420.2	-420.1	-420.1	-420.1	-420.0	-419.8	420.2	-420.3	-420.4
POPI, psia	Target	33^{+1}_{-0}	33^{+1}_{-0}	33^{+1}_{0}	33^{+1}_{-0}	46 ± 1	45^{+1}_{-0}	45^{+1}_{-0}	33^{+1}_{0}	33^{+1}_{-0}	45^{+1}_{-0}	45^{+1}_{-0}	45^{+1}_{-0}	33^{+1}_{-0}
	Actual	33.5	33 7	33.8	33.4	45.7	45.4	44.5	32.8	33.5	45 8	45.6	45.2	33.3
TOPI, °F	Target	-294.5 ± 0.4	-294.5 ± 0 4	-294 5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0 4	-294.5 ± 0.4	-294.5 + 0.4	294.5 ± 0.4	-294.5 ± 0.4	-294 5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4
	Actual	-294.7	-294.5	-294 5	-294.4	-294.4	-294.5	-294.6	-294.4	-294 4	-294.4	294.6	-294 3	-294.5
PFST, psia	Target	1250 ± 10	1300 ± 10	1250 ± 10	1250 ± 10	1225 ± 10	1380 ± 10	1380 ± 10	1300 + 10	1250 ± 10	1300 ± 10	1400 ± 10	1380 ± 10	1300 ± 10
	Actual	1242	1295	1237	1243	1229	1378	1380	1300	1248	1304	1400	1382	1302
TFST, °F	Target	-140 ± 10	-265 ± 10	-140 ± 10	-140 ± 10	-250 ± 10	-270 ± 10	-270 + 10	-300 ± 10	-140 ± 10	-300 ± 10	-240 ± 10	-270 ± 10	-300 + 10
	Actual	-144	-268	-140	-147	-250	270	-268	-303	-138	-300	236	-271	-304
TTC, °F	Target	-80^{+20}_{-10}	-200 ± 25	-275 ± 25	-200 ± 25	-235 ± 15	-275 ± 25	-150^{+20}_{-10}	-150^{+20}_{-10}	-275 + 25	-275 ± 25	-150^{+20}_{-10}	-150^{+20}_{-10}	-150^{+20}_{10}
	Actual	-83	-206	-282	-198	-229	-278	-137	-150	-281	-269	-142	-149	-150
TFTD, °F	Target	0 ± 25	$+170^{+15}_{-0}$	-100 ± 20	-100 ± 20	---	---	-	---	---	50 ± 25	50 + 25	50 ± 25	50 ± 25
	Actual	+2	+178	-83	-90	---	---	---	-	---	49	45	47	61
TSOVAL, °F	Target	---	---	---	---	---	-	---	- -	--	---	--	---	---
	Actual	---	---	---	---	---	--	---	---	---	---	--	---	-
TSOVC, °F	Target	-150 ± 50	-150 ± 50	-150 + 50	-150 + 50	100 ± 50	-100 ± 50	-100 + 50	-100 ± 50	-100 ± 50	-100 ± 50	-100 + 50	-100 ± 50	-100 ± 50
	Actual	-105	-143	-180	-183	-88	-126	-130	-131	-137	-63	-100	-84	-100
TBHR, °F	Target	---	---	---	---	---	---	---	---	---	---	---	---	---
	Actual	---	---	---	--	---	---	---	---	---	---	---	---	-
TSTDVOC, °F	Target	---	---	---	---	50 ± 25	50 ± 25	50 ± 25	50 ± 25	50 + 25	50 ± 25	50 ± 25	50 ± 25	50 + 25
	Actual	---	---	---	---	3	59	57	55	45	69	61	60	50
Altitude, ft	Target	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
	Actual	102,000	102,400	106,900	105,700	95,500	102,900	103,500	104,200	103,700	89,800	100,800	100,800	99,900

TABLE I (Continued)

Firing Number		1901-01C	1901-01D	1901-01E	1901-02A	1901-02B	1901-02C	1901-02D	1901-03A	1901-03B	1901-03C	1901-03D	1901-04A	1901-04B
PFPI, psia	Target	26.5 + 0 5	41 + 1	41 ± 1	26.5 ± 0.5	26.5 ± 0.5	26.5 ± 0.5	41 ± 1	41 ± 1	26.5^{+1}_{-0}	26.5^{+1}_{-0}	26.5^{+1}_{-0}	26.5^{+1}_{-0}	26.5^{+1}_{-0}
	Actual	26.7	41.1	40.6	26 3	26.7	26.6	40.7	41.0	27.1	26.5	26.9	28.0	27.1
TFPI, °F	Target	-420 4 ± 0.4	-420.4 ± 0.4	420.4 ± 0.4	-420.4 ± 0.4	-420.4 ± 0.4	-420 4 ± 0.4	-420.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 + 0.4	-421.4 + 0.4	-421.4 + 0.4	-421.4 ± 0.4
	Actual	-420.2	-420 0	-420.0	-420.2	-420.1	-420.4	-420.0	-421.2	-421.3	-421.8	-421.2	-421.5	-421.1
POPI, psia	Target	45^{+1}_{0}	45^{+1}_{-0}	33^{+1}_{-0}	33^{+1}_{-0}	33^{+1}_{-0}	45^{+1}_{-0}	33^{+1}_{-0}	33^{+1}_{-0}	45^{+1}_{-0}	45^{+1}_{-0}	45^{+1}_{-0}	45^{+1}_{-0}	45^{+1}_{-0}
	Actual	45.8	45.8	32.4	33 9	33.4	45.6	33.0	33.5	45.1	45.6	45.0	45.2	45.3
TOPI, °F	Target	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 + 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-294.5 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295 0 ± 0.4	-295.0 ± 0 4	-295.0 ± 0.4
	Actual	-294.4	-294.3	-294.5	294.6	294 8	294.8	-294.6	-295.0	-295 3	-295.1	-295.1	-295.0	-295.2
PFST, psia	Target	1400 + 10	1400 ± 10	1250 ± 10	1200 ± 10	1250 ± 10	1200 ± 10	1400 ± 10	1400 ± 10	1300 ± 10	1400 ± 10	1300 ± 10	1400 ± 10	1300 ± 10
	Actual	1396	1397	1250	1203	1247	1205	1372	1369	1301	1390	1297	1381	1291
TFST, °F	Target	-240 ± 10	-240 ± 10	140 ± 10	-200 ± 10	-140 ± 10	-300 ± 10	-140 ± 10	-200 ± 10	-215 ± 10	-200 ± 10	-265 ± 10	200 ± 10	-265 ± 10
	Actual	-243	-240	-135	-196	-137	-300	142	-200	-214	-203	-268	-217	-266
TTC, °F	Target	-275 ± 25	-150^{+20}_{-10}	-275 + 25	275 ± 25	-275 ± 25	-275 ± 25	-150^{+20}_{-10}	-80^{+20}_{-10}		-250 ± 25	--	-80^{+20}_{-10}	---
	Actual	-275	-152	-278	-280	-272	-275	-151	-65	---	-242	---	-67	---
TFTD, °F	Target	50 ± 25	50 + 25	-100 + 20	-100 ± 20	-100 ± 20	50 ± 25	-100 ± 20	50^{+0}_{-50}	170^{+15}_{-0}	50^{+0}_{-50}	170^{+15}_{-0}	50^{+0}_{-50}	170^{+10}_{-5}
	Actual	41	62	-103	-81	-95	46	-69	46	186	41	161	45	185
TSOVAL, °F	Target	---	- -	---	---	---	---	---	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
TSOVC, °F	Target	-100 ± 50	-100 ± 50	-100 + 50	-100 ± 50	100 ± 50	100 ± 50	-100 ± 50	-150 ± 50	-150 + 50	-150 + 50	-150 ± 50	-150 ± 50	-150 ± 50
	Actual	-101	-92	-87	-135	-63	-78	-86	-144	-146	-159	-154	-106	-132
TBHR, °F	Target	---	---	---	---	---	---	-	---	---	-	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	-	---	---	---
TSTDVOC, °F	Target	+50 ± 25	50 ± 25	50 ± 25	50 ± 25	50 ± 25	50 ± 25	50 ± 25	---	---	---	---	- -	---
	Actual	148	53	50	25	55	51	51	---	---	---	---	---	---
Altitude, ft	Target	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
	Actual	100,500	103,500	109,400	99,500	100,700	102,900	103,500	99,800	106,100	105,900	103,800	77,800	100,000

TABLE I (Continued)

Firing Number		1901-04C	1901-04D	1901-05A	1901-06A	1901-06B	1901-06C	1901-06D	1901-06E	1901-07A	1901-07B	1901-07C	1901-07D	1901-07E
PFPI, psia	Target	41.0 ± 1	41.0 ± 1	41 ± 1	26.5^{+1}_{0}	26.5^{+1}_{-0}	26.5^{+1}_{-0}	26.5^{+1}_{-0}	26.5^{+1}_{-0}	26.5^{+1}_{-0}	26.5^{+1}_{-0}	26.5^{+1}_{-0}	26.5^{+1}_{-0}	41^{+1}_{-0}
	Actual	40.7	40.7	43.1	27.2	26.6	26.2	26.4	27.2	27.0	26.7	26.8	27.0	41.3
TFPI, °F	Target	-421.4 ± 0.4	-421.4 ± 0.4	-420.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4
	Actual	-421.5	-421.3	-420.6	-421.3	-420.6	-421.7	-421.2	-421.2	-421.5	-421.0	-421.7	-420.7	-421.4
POPI, psia	Target	45^{+1}_{-0}	45^{+1}_{-0}	33 ± 1	33 ± 1	45^{+1}_{-0}	33 ± 1	45^{+1}_{-0}	33 ± 1	45^{+1}_{-0}	45^{+1}_{-0}	45^{+1}_{-0}	45^{+1}_{-0}	33 ± 1
	Actual	45.7	45.8	32.7	33.7	45.4	33.7	45.2	32.0	45.1	45.4	45.7	45.2	32.5
TOPI, °F	Target	-295.0 ± 0.4	295.0 ± 0.4	-294.5 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4
	Actual	-295.1	-294.8	-294.8	-295.4	-295.2	-294.9	-294.7	-293.9	-295.0	-294.9	-294.5	-294.5	-293.1
PFST, psia	Target	1400 ± 10	1300 ± 10	1400 ± 10	1250 ± 10	1300 ± 10	1250 ± 10	1300 ± 10	1250 ± 10	1400 ± 10	1300 ± 10	1250 ± 10	1200 ± 10	1260 ± 10
	Actual	1399	1294	1374	1258	1313	1263	1312	1254	1373	1303	1236	1212	1254
TFST, °F	Target	-200 ± 10	-265 ± 10	-140 ± 10	-140 ± 10	-265 ± 10	-140 ± 10	-265 ± 10	-140 ± 10	-200 ± 10	-265 ± 10	-200 ± 10	-260 ± 10	-140 ± 10
	Actual	-207	-262	-142	-143	-267	-140	-265	137	-199	-269	-202	-264	-144
TTC, °F	Target	-80^{+20}_{-10}	---	-150^{+20}_{10}	-200 ± 25	---	-250 ± 25	-200 ± 25	-200 ± 25	-250 ± 25	---	-250 ± 25	---	-275 ± 25
	Actual	-71	---	-154	-203	---	-248	-217	-199	-242	---	-239	---	-276
TFTD, °F	Target	50^{+0}_{-50}	170^{+10}_{-5}	-100 ± 20	-100 ± 20	170^{+15}_{-0}	-100 ± 20	170^{+15}_{-0}	-100 ± 20	50^{+0}_{-50}	170^{+15}_{-0}	50^{+0}_{-50}	170^{+15}_{-0}	-100 ± 20
	Actual	34	167	-86	-75	174	-86	173	-95	35	170	44	170	-107
TSOVAL, °F	Target	-	---	---	---	---	---	---	---	--	---	---	---	---
	Actual	---	-	---	---	---	---	---	---	---	---	---	---	---
TSOVC, °F	Target	-150 ± 50	-150 ± 50	-100 ± 20	-150 ± 50	-150 ± 50	150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50
	Actual	151	-146	-142	-121	-147	-176	171	184	-128	-154	-172	-162	-127
TBHR, °F	Target	---	---	-	---	---	---	---	---	---	- -	---	---	---
	Actual	-		---	---	---	---	---	---	---	---	---	---	---
TSTDVOC, °F	Target	---	---	50 ± 25	-	---	---	--	---	---	--	---	---	---
	Actual	--	-	61	---	---	---	---	---	---	---	---	---	---
Altitude, ft	Target	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
	Actual	100,300	99,600	102,600	89,100	100,200	103,200	102,700	109,600	92,400	100,200	98,200	99,100	100,500

TABLE I (Continued)

Firing Number		1901-08A	1901-08B	1901-08C	1901-08D	1901-08E	1901-09A	1901-09B	1901-09C	1901-09D	1901-09E	1901-09F	1901-10A	1901-10B
PFPI, psia	Target	41 ± 1	26.5^{+1}_{-0}	26.5^{+1}_{-0}	41 ± 1	26.5^{+1}_{-0}	34 ± 1	34 ± 1	26.5^{+1}_{-0}	34 + 1	41 ± 1	34^{+1}_{-0}	26.5^{+1}_{-0}	26.5^{+1}_{-0}
	Actual	41.3	27.2	27.2	41.0	27.4	33.8	33.7	26.9	33.5	40.7	33.1	26.6	27.0
TFPI, °F	Target	-420.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 + 0.4	-421.4 + 0.4	-421.4 + 0.4	-421.4 + 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4
	Actual	-420.7	-421.3	-421.5	-421.0	-421.0	-421.4	-421.6	-421.4	-421.7	-421.3	-421.2	-421.5	-421.3
POPI, psia	Target	33^{+1}_{-0}	45^{+1}_{-0}	45^{+1}_{-0}	45^{+1}_{-0}	45^{+1}_{-0}	40 ± 1	40 ± 1	45^{+1}_{-0}	40 ± 1	45^{+1}_{-0}	40 ± 1	33± 1	33 ± 1
	Actual	34.8	45.8	45.8	44.8	45.1	39.5	39.7	45.2	39.6	45.0	39.0	33.6	33.8
TOPI, °F	Target	-294.5 ± 0.4	-295.0 ± 0.4	-295.0 + 0.4	-295.0 + 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4
	Actual	294.6	295.2	-295.2	-295.0	-294.7	-295.3	-295.2	-295.1	-295.0	-294.6	-294.6	-295.1	-295.3
PFST, psia	Target	1400 ± 10	1300 ± 10	1400 ± 10	1300 ± 10	1400 ± 10	1200 + 10	1000 ± 10	1300 ± 10	800 ± 10	1300 ± 10	600 ± 10	1250 ± 10	1200 ± 10
	Actual	1375	1298	1367	1298	1406	1195	997	1298	790	1298	602	1248	1193
TFST, °F	Target	-140 ± 10	-265 ± 10	-200 ± 10	-265 ± 10	-200 ± 10	50 ± 25	-220 ± 10	-265 ± 10	-220 ± 10	-265 ± 10	-220 ± 10	-140 ± 10	50 ± 25
	Actual	-145	-268	-202	265	-204	42	-224	-272	-225	-266	-224	-140	47
TTC, °F	Target	-150^{+20}_{-10}	---	-80^{+20}_{-10}	---	-250 ± 25	-50 ± 25	-50 ± 25	---	-50 ± 25	---	-50 ± 25	-200 ± 25	-200 ± 25
	Actual	-154	---	-83	---	-244	-59	-59	---	-58	---	-53	-224	-231
TFTD, °F	Target	-100 ± 20	170^{+15}_{-0}	50^{+0}_{-50}	170^{+15}_{-0}	50^{+0}_{-50}	50 ± 25	50 ± 25	170^{+15}_{-0}	50 ± 25	170^{+15}_{-0}	50 ± 25	-100 ± 20	-100 ± 20
	Actual	-84	180	25	175	35	56	55	171	52	171	43	-73	-81
TSOVAL, °F	Target	---	---	---	---	---	---	---	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
TSOVC, °F	Target	-100 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 + 50	-150 ± 50	-150 ± 50
	Actual	-92	-141	-177	-169	-160	-121	-150	-160	-177	-167	-169	-122	-155
TBHR, °F	Target	---	--	---	---	---	---	---	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	---	---	---	---
TSTDVOC, °F	Target	50 ± 25	--	---	---	---	---	---	---	---	---	---	---	---
	Actual	52	---	---	---	---	---	---	---	---	---	---	---	---
Altitude, ft	Target	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
	Actual	90,400	102,000	100,500	99,900	102,300	88,400	100,300	99,800	100,500	100,000	102,300	80,600	100,500

TABLE I (Concluded)

Firing Number		1901-11A	1901-11B	1901-11C	1901-11D	1901-11E	1901-11F	1901-12A	1901-12B	1901-12C	1901-12D	1901-12E	1901-12F
PFPI, psia	Target	27^{+1}_{-0}	26.5^{+1}_{-0}	41 ± 1	41 ± 1	26.5^{+1}_{-0}	34 ± 1	41 ± 1	26.5^{+1}_{-0}	41 ± 1	26.5^{+1}_{-0}	41 ± 1	41 + 1
	Actual	26.8	27.1	41.2	41.1	26.9	34.2	40.9	26.8	40.9	26.8	41.0	41.3
TFPI, °F	Target	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 + 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4	-421.4 ± 0.4
	Actual	-420.7	-420.8	-421.8	-421.0	-420.6	-420.9	-421.5	-421.4	-421.6	-421.7	-421.4	-421.4
POPI, psia	Target	45^{+1}_{-0}	45^{+1}_{-0}	45^{+1}_{-0}	45^{+1}_{-0}	33 ± 1	40 ± 1	45^{+1}_{-0}	45^{+1}_{-0}	45^{+1}_{-0}	33 ± 1	45^{+1}_{-0}	45^{+1}_{-0}
	Actual	45.5	45.2	45.3	45.6	33.8	44.4	45.5	45.6	46.0	33.1	45.3	46.2
TOPI, °F	Target	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4	-295.0 ± 0.4
	Actual	-294.9	-295.1	-295.1	-294.7	-293.8	-293.1	-294.8	-295.0	-294.8	-295.3	295.0	-295.1
PFST, psia	Target	1365 ± 10	1300 ± 10	1300 ± 10	1300 + 10	1250 ± 10	600 ± 10	1400 ± 10	1400 ± 10	1300 ± 10	1200 ± 10	1400 ± 10	1300 ± 10
	Actual	1355	1308	1300	1298	1251	602	1403	1401	1305	1196	1394	1306
TFST, °F	Target	-210 ± 10	-265 ± 10	-265 ± 10	-265 ± 10	-140 ± 10	-220 ± 10	-270 ± 10	-270 ± 10	-300 ± 10	-140 ± 10	-270 ± 10	-300 ± 10
	Actual	-203	-267	-267	-267	-141	-219	-270	-270	-301	-140	-270	-300
TTC, °F	Target	-80^{+20}_{-10}	---	---	---	. .	-50 + 25	-150^{+20}_{-10}	-275 ± 25	-150^{+20}_{-10}	-275 ± 25	-150^{+20}_{-10}	-150^{+20}_{-10}
	Actual	-78	---	---	---	---	-68	-146	277	-153	-279	-148	-152
TFTD, °F	Target	50^{+0}_{-50}	170^{+15}_{-0}	---	170^{+15}_{-0}	---	50 ± 25	50^{+0}_{-50}	50^{+0}_{-50}	50^{+0}_{-50}	-100 ± 25	50^{+0}_{-50}	50^{+0}_{-50}
	Actual	28	165	---	166	---	64	30	32	19	94	29	28
TSOVAL, °F	Target	---	---	---	---	---	- -	---	---	---	---	---	--
	Actual	---	---	---	---	- -	---	---	---	---	---	---	---
TSOVC, °F	Target	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50	-150 ± 50
	Actual	-110	-130	-176	-156	-154	-178	-139	-161	-129	-115	-165	-173
TBHR, °F	Target	---	---	---	---	---	- -	---	---	--	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	--	---	---
TSTDVOC, °F	Target	---	---	---	---	---	--	---	---	---	---	---	---
	Actual	---	---	---	---	---	---	---	---	---	- -	---	---
Altitude, ft	Target	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
	Actual	84,200	100,500	98,600	102,200	105,600	107,000	85,900	97,000	97,100	96,600	98,300	100,000

TABLE II
SUMMARY OF TARGETING PRECISION

Parameter	Location of Arithmetic Mean Relative to Target Center	One Standard Deviation	Percent of Targets Met
Fuel Pump Inlet Pressure	+0.058 psi	0.613 psi	82.9
Fuel Pump Inlet Temperature	+0.093°F	0.341°F	83.6
Oxidizer Pump Inlet Pressure	+0.155 psi	0.625 psi	91.7
Oxidizer Pump Inlet Temperature	-0.002°F	0.430°F	80.5
Start Tank Pressure	-0.80 psi	8.83 psi	86.2
Start Tank Temperature	-1.65°F	4.49°F	97.0
Thrust Chamber Throat Temperature	-3.1°F	11.0°F	89.4
Crossover Duct Temperature	+0.8°F	18.3°F	78.7
Main Oxidizer Valve Closing Control Line Temperature	-8.5°F	21.3°F	48.3
Main Oxidizer Valve Actuator Temperature	+0.2°F	22.5°F	88.1
Helium Regulator Temperature	-10.9°F	14.4°F	52.1
Start Tank Discharge Valve Body Temperature	-15.5°F	22.0°F	85.5

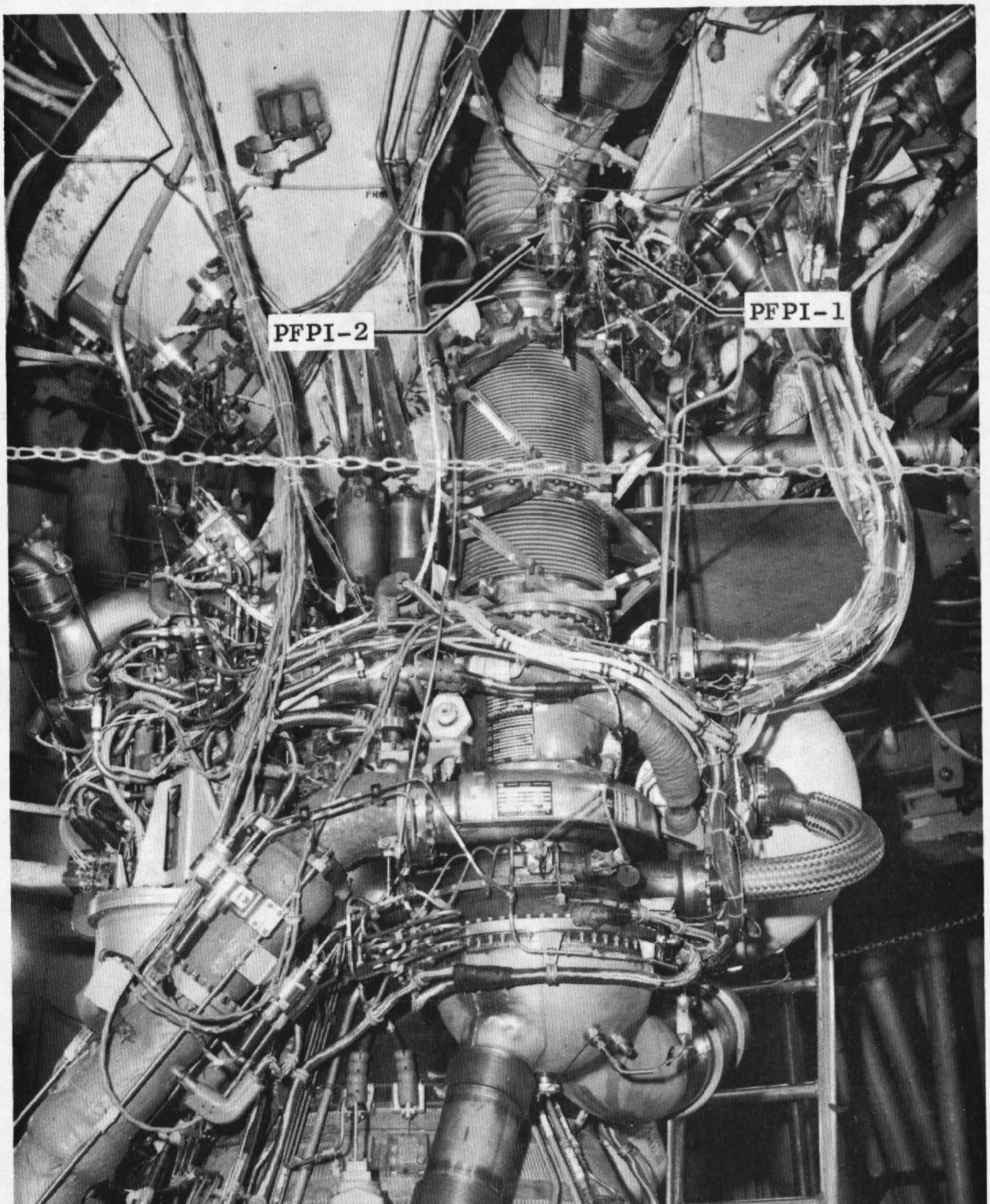
APPENDIX III
INSTRUMENTATION

The instrumentation pertinent to this report is tabulated in Table III-1. The location of selected major engine instrumentation is shown in Fig. III-1.

TABLE III-1
INSTRUMENTATION LIST

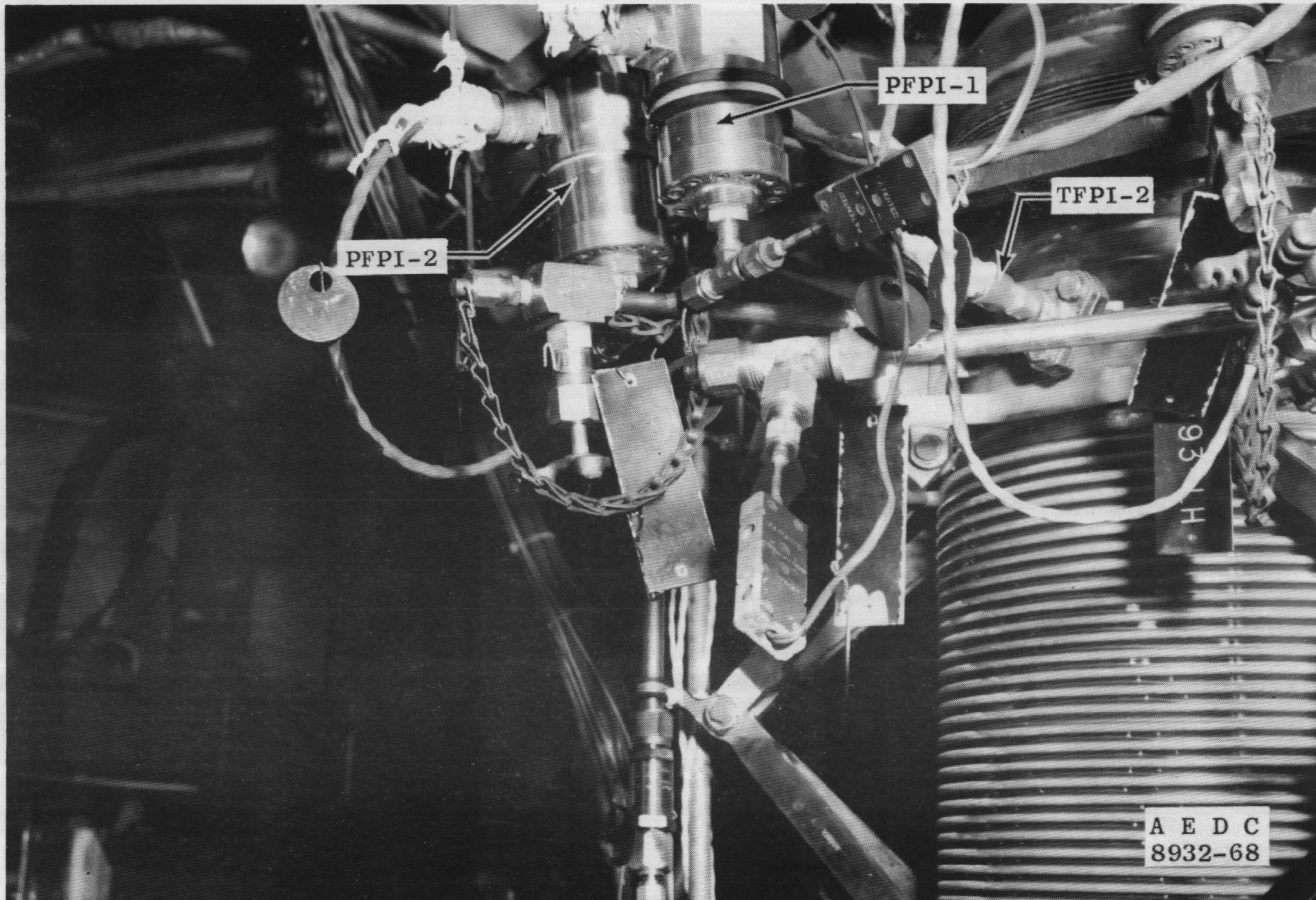
AEDC Code	Parameter	Tap No.	Range	Digital System	Strip Chart	X-Y Plotter
	Pressure		psia			
PA1	Test Cell		0 to 0.5	X		
PA2	Test Cell		0 to 1.0	X		
PA3	Test Cell		0 to 5.0	X	X	
PFPI-1	Fuel Pump Inlet		0 to 100	X		X
PFPI-2	Fuel Pump Inlet		0 to 100[1]	X		X
PFST-2	Fuel Start Tank	TF1	0 to 1500	X		X
POPI-1	Oxidizer Pump Inlet		0 to 100	X		X
POPI-2	Oxidizer Pump Inlet		0 to 200	X		X
	Temperature		°F			
TBHR-2	Helium Regulator Body		-100 to +50	X	X	
TFPI-1	Fuel Pump Inlet		-425 to -400	X		X
TFPI-2	Fuel Pump Inlet		-425 to -400	X		X
TEST-2	Fuel Start Tank	TFTI	-350 to +100	X		X
TFTD-3	Fuel Turbine Discharge Duct		-200 to +1000	X	X	
TOPI-1	Oxidizer Pump Inlet		-310 to -270	X		X
TOPI-2	Oxidizer Pump Inlet		-310 to -270	X		X
TSOVAL-2	Oxidizer Valve Closing Control Line		-200 to +100	X	X	
TSOVC-1	Oxidizer Valve Actuator Cap		-325 to +150	X		
TSTDVOC	Start Tank Discharge Valve Opening Control Port		-350 to +100	X		
TTC-1P	Thrust Chamber Jacket (Control)	CS1	-425 to +500	X	X	

[1]Before test period J4-1801-31 the range of PFPI-2 was 0-200 psia.



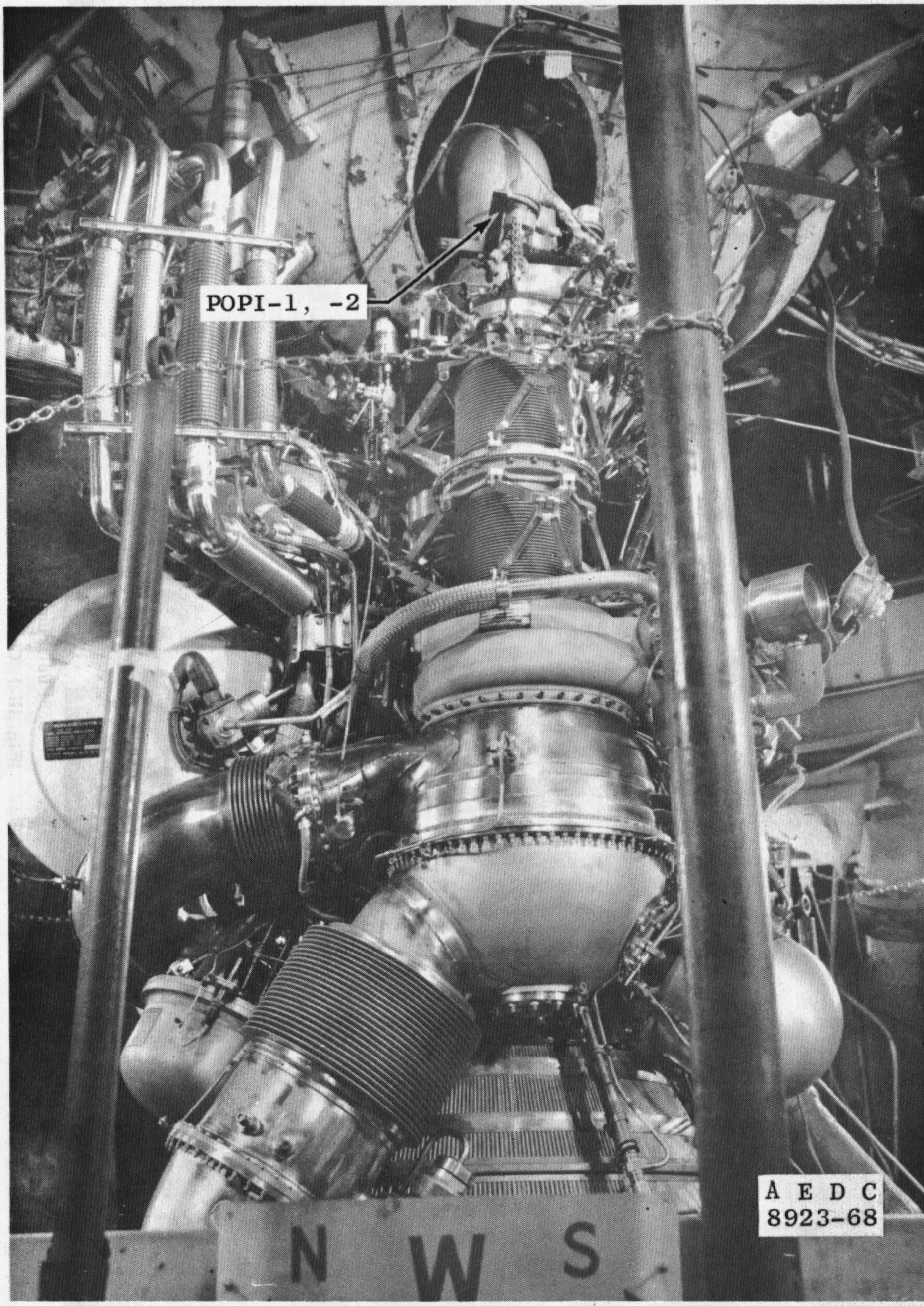
a. Fuel Pump

Fig. III-1 Instrumentation Locations

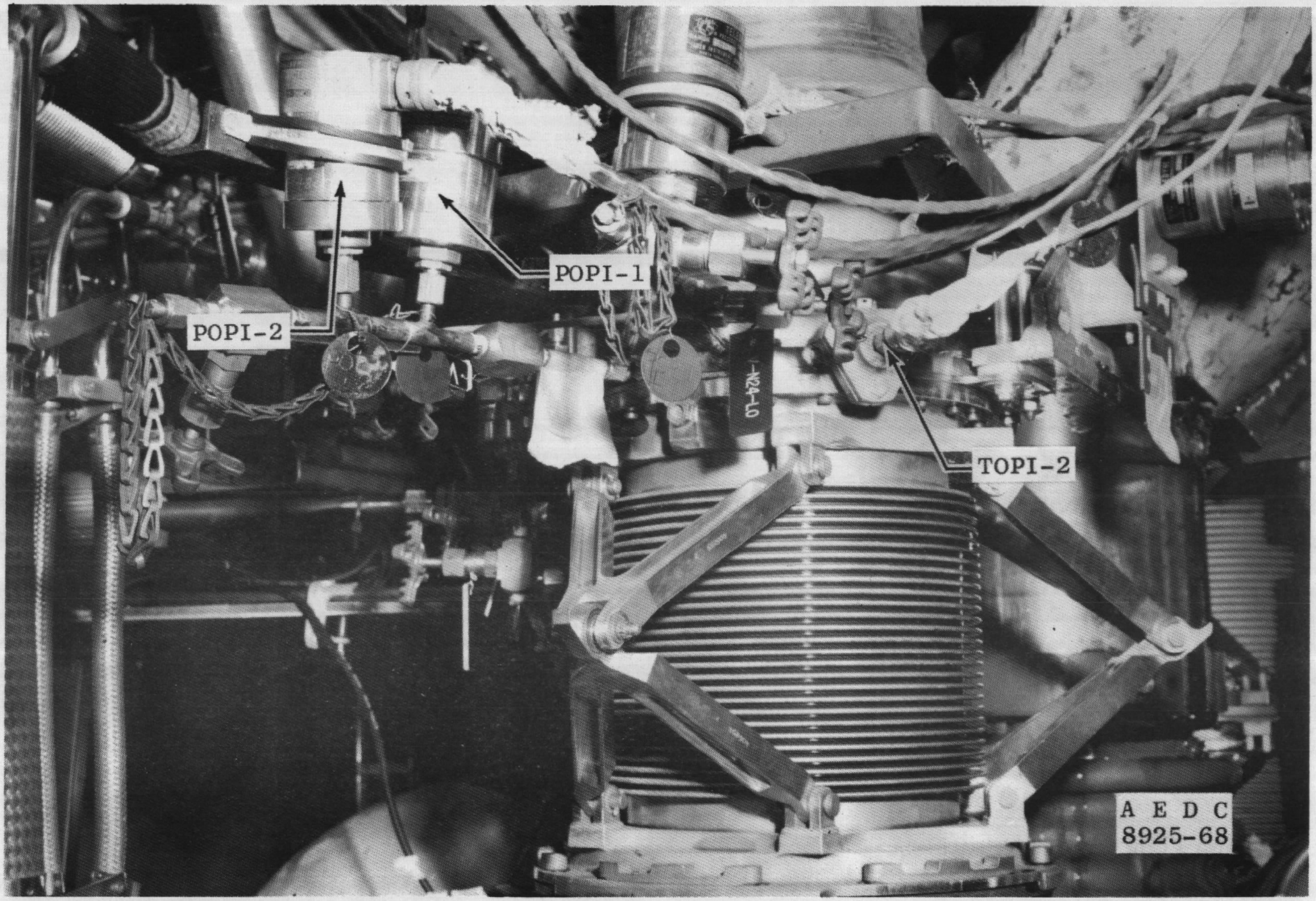


b. Fuel Pump

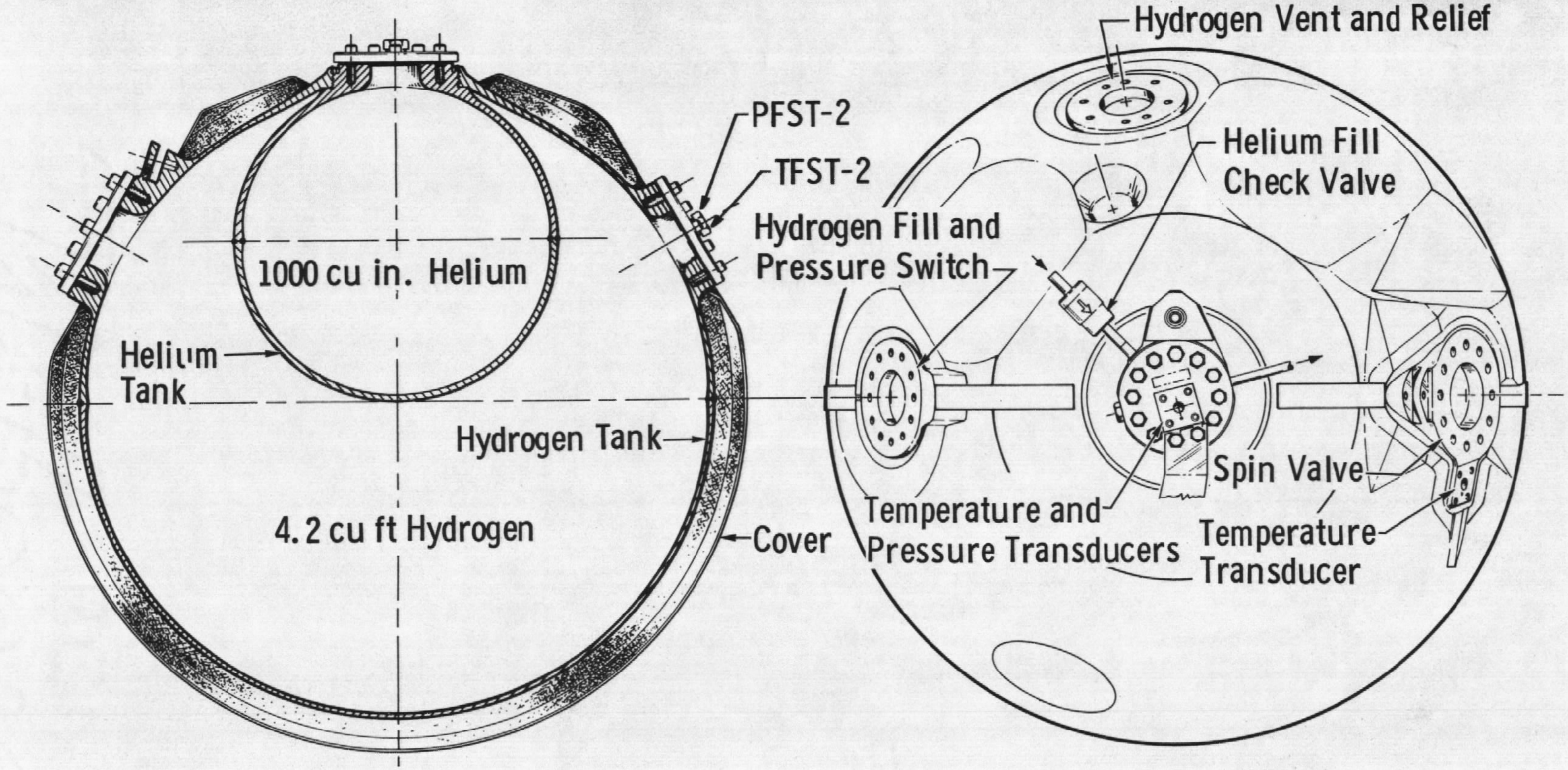
Fig. III-1 Continued



c. Oxidizer Pump
Fig. III-1 Continued

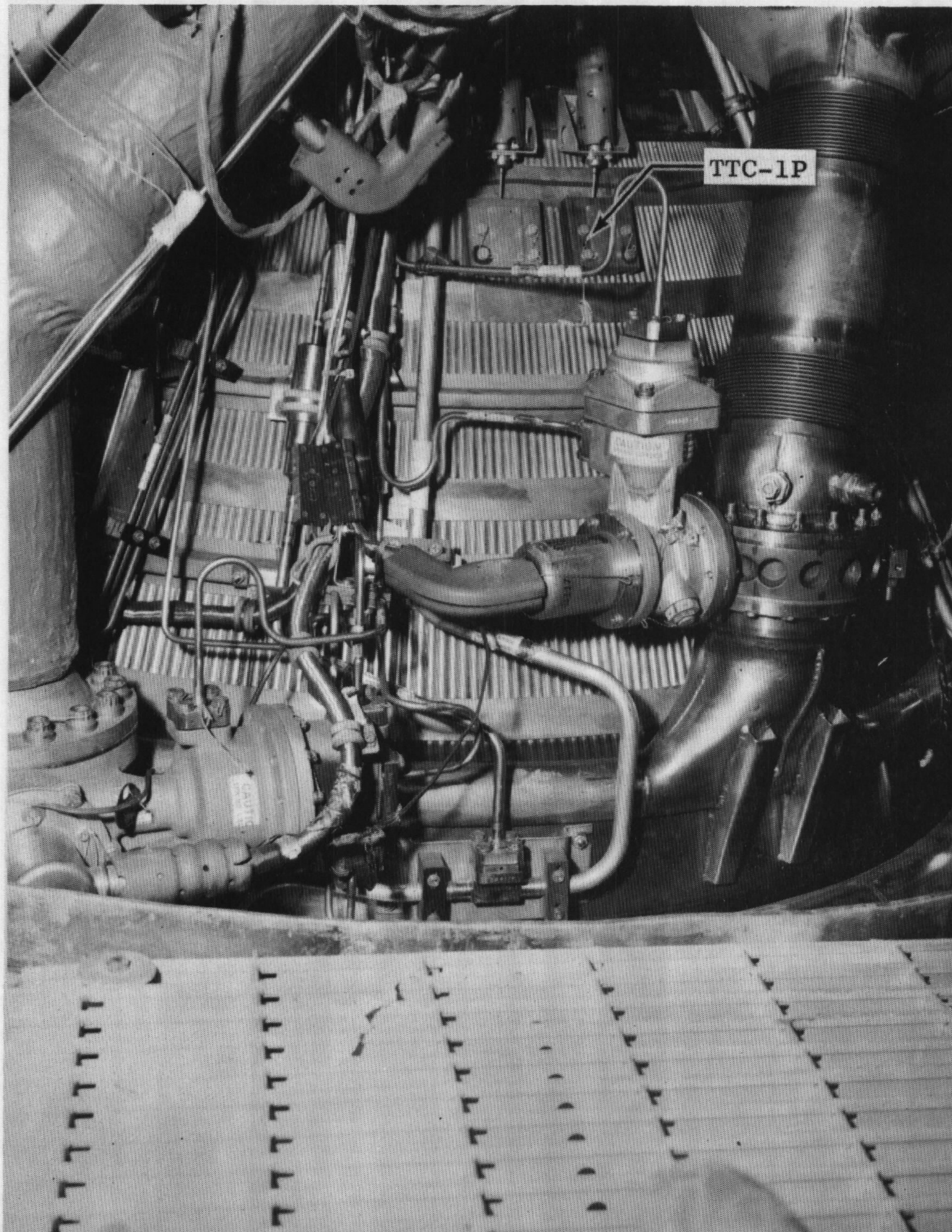


d. Oxidizer Pump
Fig. III-1 Continued

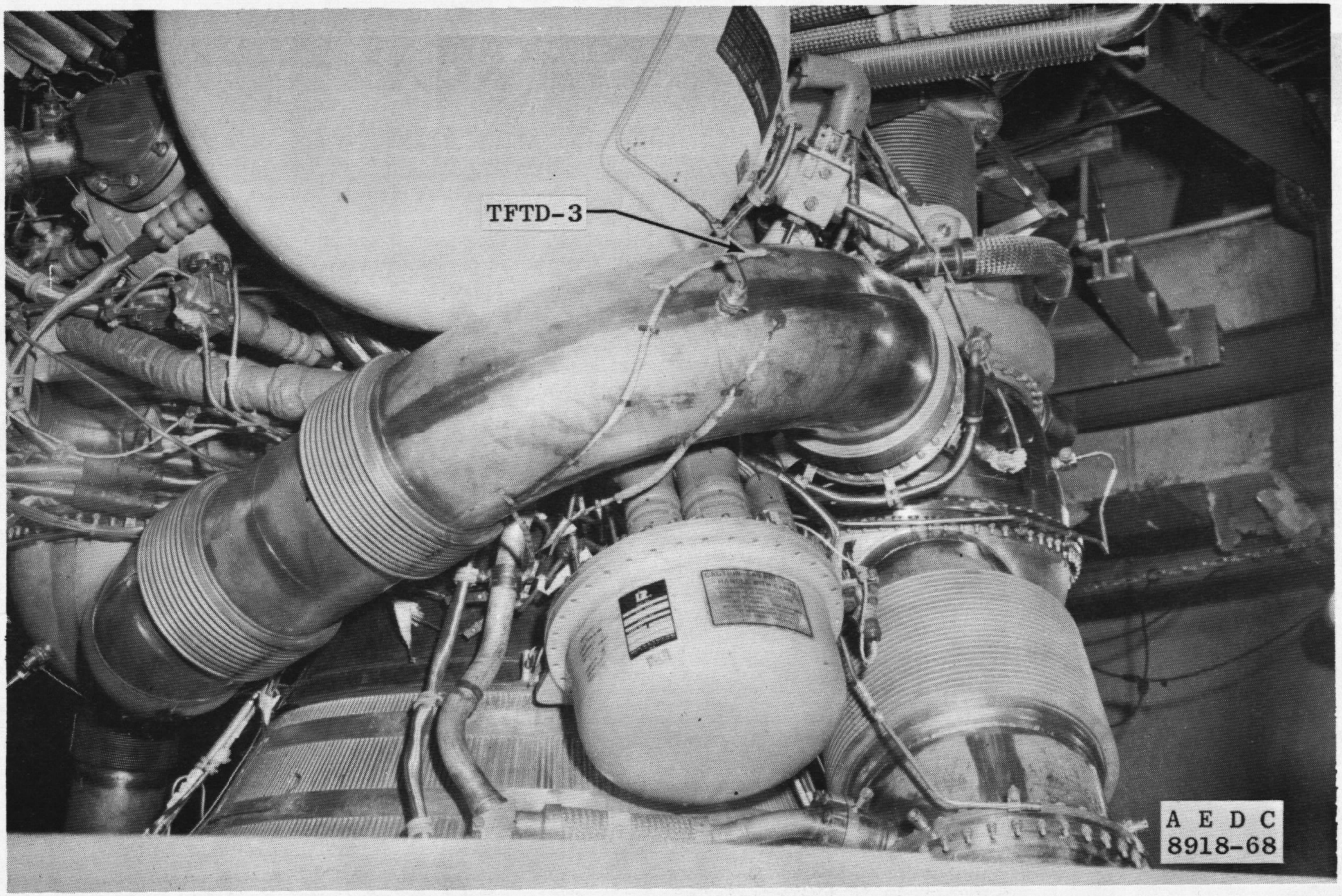


e. Start Tank

Fig. III-1 Continued

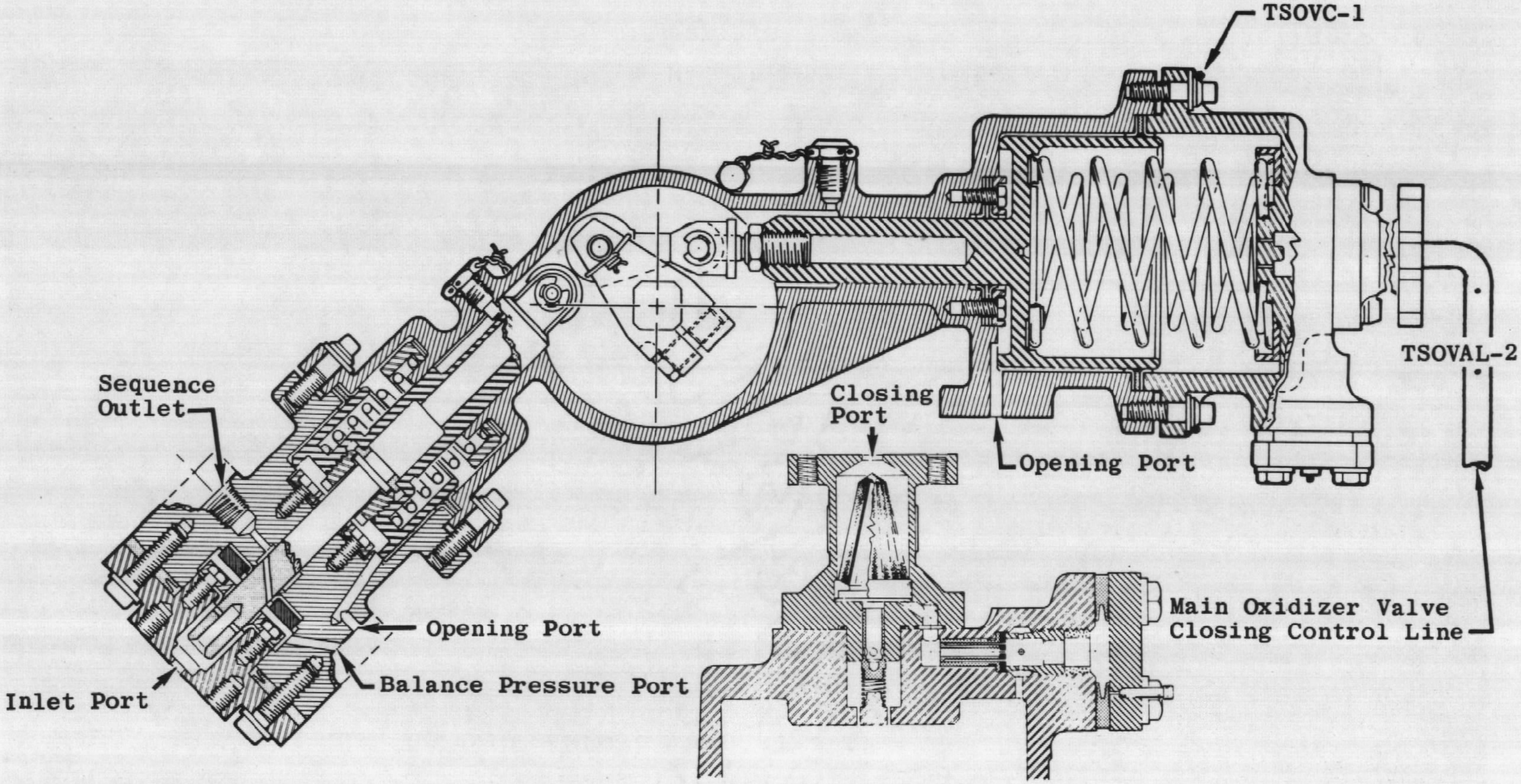


f. Thrust Chamber
Fig. III-1 Continued



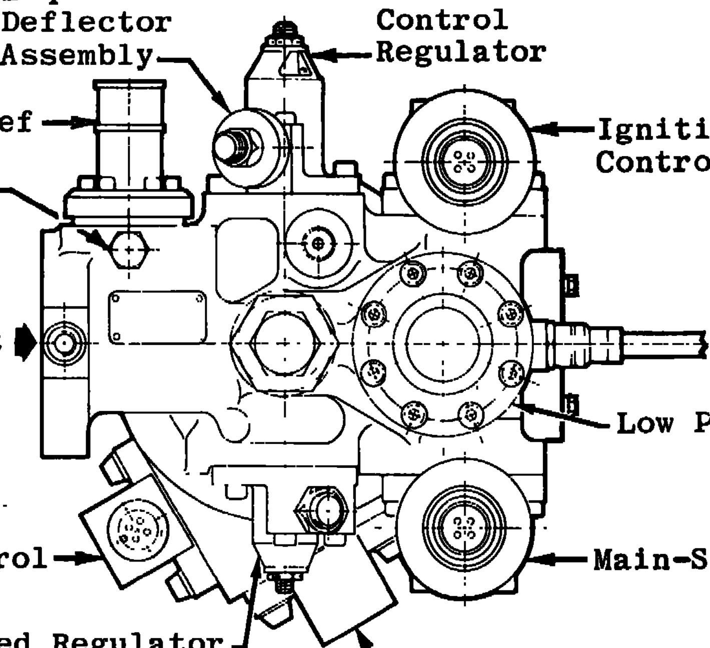
g. Crossover Duct

Fig. III-1 Continued



h. Main Oxidizer Valve

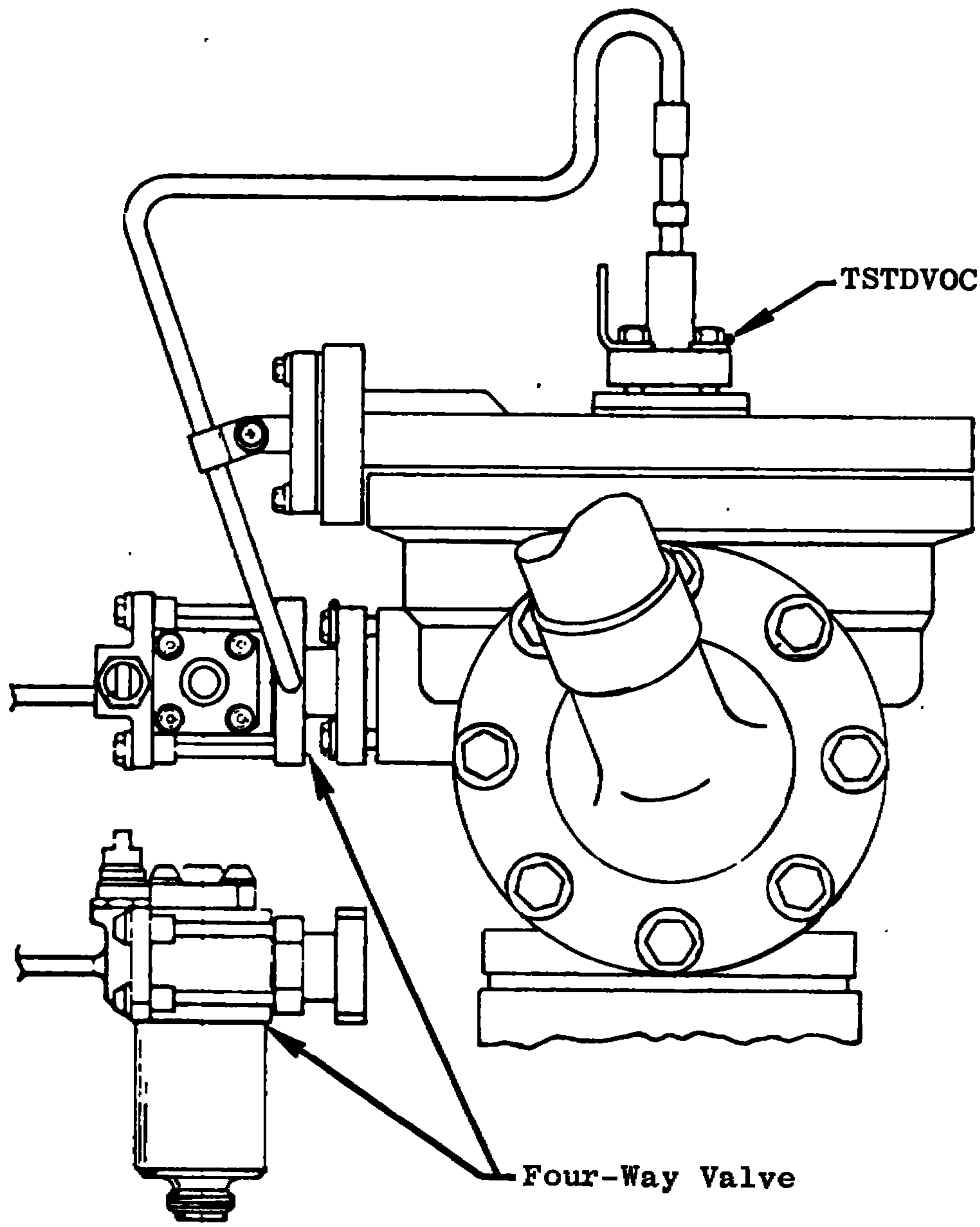
Fig. III-1 Continued



Top View

i. Helium Regulator

Fig. III-1 Continued



j. Start Tank Discharge Valve
Fig. III-1 Concluded

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13. ABSTRACT
Testing of the Rocketdyne J-2 engine using an S-IVB battleship stage was conducted at AEDC from July 1966 through October 1968 in Propulsion Engine Test Cell (J-4) of the Large Rocket Facility (LRF) in support of the J-2 application on the Saturn IB and Saturn V launch vehicles for the NASA Apollo program. Throughout this test program various temperature and pressure parameters were assigned target values at engine start for the purpose of assuring safe engine operation, for producing predicted flight conditions, or for duplicating actual flight conditions. The work reported herein is a basic statistical analysis performed on thirteen of those targeted parameters for the purpose of determining the precision with which the test facility met these engine start targets.

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1. Rocket motor -- J-2
2 " " -- Performance
3 Missiles -- Saturn
3 " -- Apollo

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